RESIDENTIAL DEMAND FOR ELECTRICITY IN MASSACHUSETTS

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I. Introduction

In this study we make use of high quality disaggregated data on prices, income, consumer durable stocks, and other variables to estimate residential demand for electricity in Massachusetts.[1]

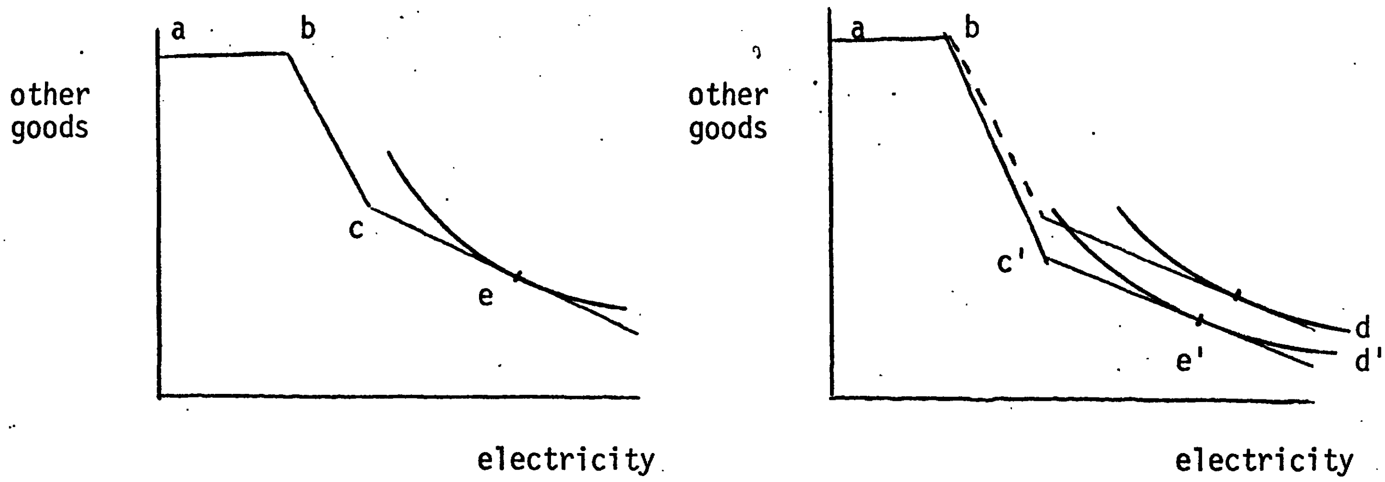
In Part II below we discuss problems with the empirical specification of electricity demand, both short run and long run. In Part III we discuss the data in detail. In Part IV we present and discuss the results of the estimation. Part V is a note on "lifeline" electricity rates. Finally, we summarize the conclusions in Part VI. An appendix lists the data sources.

II. Problems in Estimating Electricity Demand

Declining Block Pricing: Infra-Marginal Price Changes

It has long been recognized that there are simultaneity problems involved in estimating electricity demand. This is because electricity is typically sold under a declining block schedule, so that marginal and average prices are jointly dependent with quantity consumed. We will take up this issue in the next section.

A second issue, and one which was unrecognized until (Taylor, 1975), is that declining block pricing also implies that both infra-marginal and marginal prices should enter the demand equation; and that changes in infra-marginal prices have income effects on demand. To see this consider the consumer whose indifference curve between electricity and other goods is shown in Figure 1. A two-part declining block schedule with a constant base fee is represented by the price line abcd, Panel (a). The consumer is in equilibrium at point e, facing a marginal price equal to the slope of segment cd. Now the rate on the infra-marginal block only is increased. The new price line is abc'd', Panel (b). The consumer will move to a new equilibrium at e', consuming a smaller quantity of electricity at the same marginal price. Segments cd and c'd' are parallel; the reduction in quantity consumed is the result of an income effect and not of a substitution effect.[2] Thus, regression equations for the demand for electricity should include both marginal and infra-marginal prices, for different reasons. And, as Taylor points out, when the infra-marginal



(a) Figure 1 (b)

price is neglected the effect is to bias upward estimates of the price elasticity of demand, because infra-marginal and marginal prices are typically positively correlated.

The infra-marginal portion of a residential electric bill can be thought of as the lump-sum portion of a two-part tariff. If we know the actual rate schedule under which electricity is purchased, as we do here, we can calculate the change for each customer and include it in the demand equation. Since it represents an income effect, we expect its coefficient to equal minus one times the coefficient of income.

Declining Block Prices: Simultaneity

Contrary to (Taylor, p.79), our use of actual rate schedule data does not eliminate the problem of simultaneity since, except in a special case, marginal and infra-marginal prices still will be jointly determined with quantity consumed. The supply schedule faced by each purchaser is a declining block, so that price depends upon quantity consumed. (Note that, given this kind of supply schedule, price is a single-valued function of quantity supplied, but not vice versa.)

Every consumer faces a different declining block; this identifies the demand curve. From a formal point of view we may consider each particular electric utility district's declining block supply schedule to be the result of an industry supply schedule shifted by some unspecified utility district-specific variable. We shall not estimate this function, but the reader should not think that this implies some "identification problem ." We use non-stochastic supply schedules which show variation in supply conditions, and it is this which identifies the demand function, rather than the presence of exogenous variables in another regression equation. The relevant issue is possible biases in different estimators; to this issue we now turn.

Ordinary least squares estimates of the demand function will be biased if price is not exogenous. There is a special case, however, which may be practically important, where declining block prices cause no estimation problems.

Suppose that changes in marginal or infra-marginal prices cause the consumer to alter quantity purchased, but always by staying within a given block (contrary to the situation described in footnote 1). In this case both marginal and infra-marginal prices are exogenous to the consumer, and so simultaneity problems disappear.

As a rough test for simultaneity we might compare the residual at each observation to that observation's rate blocks. If the residual is smaller than the quantity change required to move into the next block, in either direction, then we may be fairly certain that there is little chance for potential switches.

Now, if price is endogenous then OLS estimates of the demand price elasticity will be biased. We will estimate a logarithmic demand function. It can be shown[3] that the estimated price elasticity is related to the true elasticity as follows:

$$E(\hat{\varepsilon}) = \varepsilon + (\eta-\varepsilon)\,\lambda$$

where $\hat{\varepsilon}$ = estimated demand price elasticity,

ε = true demand price elasticity,

η = true supply price elasticity

λ = a function of the errors in the supply and demand equations.

Normally $\eta>0$, $\varepsilon<0$. Here $\eta<0$ because of declining block pricing, and this tends to reduce the magnitude of the bias. Also, we know that the curve we estimate is bounded by the supply and demand schedules. But while typically we could say that this implied an upward bias in demand price elasticity estimates, here we cannot know this since it is possible that demand and supply have the configuration of Figure 2.

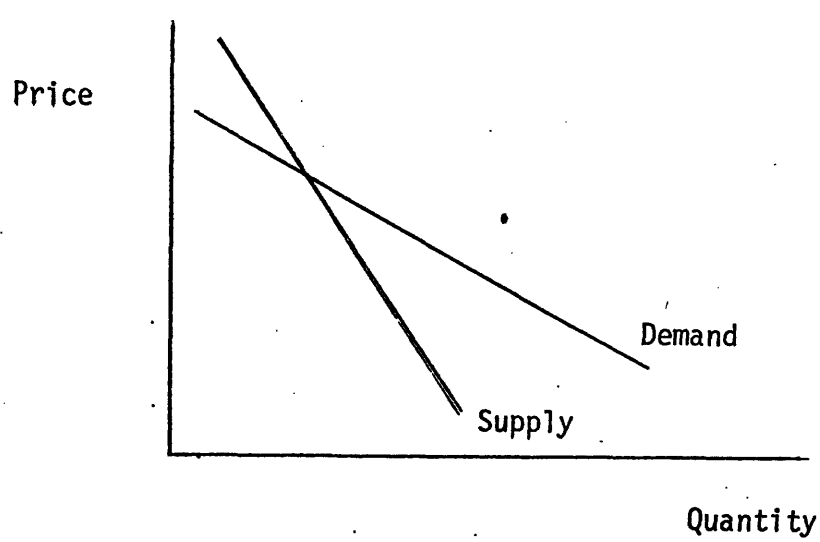


Figure 2 -

In fact, however, for reasons discussed in Section IV below, we are inclined to expect some positive bias.

Stocks of Consumer Durables

While the importance of owned stocks of electricity using appliances as a determinant of the demand foe electricity has long been recognized, lack of adequate data on these stocks has usually precluded their use in empirical work. Hence two sets of questions have gone largely unanswered.

First, to what extent do stocks explain short run variation in demand? In particular, how does this variation depend on the composition of the stocks? Fisher and Kaysen suggested that electricity demand would become more income elastic over time for reasons having to do with the distribution of stocks. Conservationists point to the high energy use of appliances like color televisions and frost-free refrigerators, supposedly "discretionary" appliances. Apart from increasing demand for electricity, do these have systematic effects on the price elasticity of demand?

The second unanswered set of questions concerns the effect of energy prices on the demand for these consumer durables, since in the long run the demand for electricity is essentially the demand for electricity-using durable goods. Evidence on this point is mixed.[4]

In the short run the demand for electricity by the household (q_d) depends upon its price (P_e), household income (Y), the stocks of various electricity using appliances (S), and various other relevant variables such as weather and housing characteristics (W):

$$q_d = q_d(P_e, Y, \underline{S}, W).$$

The prices of competing energy sources do not enter in the short run since there is no scope for substitution out of electrically run appliances into alternative gas and oil fueled appliances.

Note that $\underline{S}$ is in fact a vector of appliances. Different assets have different characteristics which permit varying degrees of discretion in the choice of utilization rates. And furthermore, we expect the distribution of these assets to differ systematically among consumers, primarily as a function of income. This is why we choose not to measure short-run variation in electricity demand as variation in a stock utilization rate. An implicit assumption of such a procedure would be that the long-run utilization rate is a constant. We maintain, on the contrary, that the long-run utilization rate is endogenous for two reasons: 1) For the same reason that the short-run rate is endogenous; namely, that it now pays to set the thermostat back a few degrees etc.; and 2) Because increases in real income will result in changes in the composition of owned assets that systematically change the aggregate utilization rate. Thus if income explains variation in the utilization rate, it is at least partly because income explains the particular distribution of electricity using assets.

In the long run the demand for a stock of each type of electric appliance (S_i) depends upon the expected relative prices of competing fuels, the rental price of this (P_i) and competing assets (P_j), and income (Y):

$$S_i = S_i(P_{elec.}, P_{gas}, P_i, P_j, Y)$$

where i = refrigerators, heating systems, etc.

Costs of adjustment insure, however, that consumers will not immediately bring their stocks in line with desired stock levels. Such costs vary among assets. Costs of installation differ, and there are better developed markets, say, in used televisions than for used home heating systems. Consequently we should expect different adjustment speeds for different asset types.

For each asset type, then, one possible procedure would be to model a distributed lag partial adjustment model. Together with the short run information this would permit estimation of short run and long elasticities, as well as elasticity of demand for any intermediate length of time. This requires a time series data set which displays variation in asset rental prices as well as energy prices. As we shall see below, we do not have sufficient data to follow this procedure.

As an alternative we estimate a logit model of residential appliance choice.[5] The logit procedure recognizes that the choice of appliance type (oil vs. electric water heat for example) is a discrete choice of a particular durable goods for any given household. Observed shares of each appliance type in the sample are assumed to correspond to the subjective probabilities of these choices by a "typical consumer." The regression equations generate "probability elasticities" with respect to right-hand-side variables.

The form of the regression equations (in the case of three alternatives) is

$$\log (M_1/M_3) = a_0 + a_1P_1 + a_2P_2 + \dots + u_1$$

$$\log (M_2/M_3) = b_0 + b_1P_1 + b_2P_2 + \dots + u_2$$

$$M_1 + M_2 + M_3 = 1$$

where M_i is the share of the i^{th} appliance type.

III. Data

The Commonwealth of Massachusetts is served by fifty electric utilities. Some of these supply residential electricity under several rate schedules; all-electric as well as standard, for example. The unit of observation for this study is the average consumer on each residential rate schedule.

We discard eleven utilities at the outset. These discarded observations correspond to geographical areas where there is no natural gas service. All are rural and very small. The remaining sample still covers over 98% of the population of the state.

For the remaining 39 electric utility districts we collect data for purchase under a total of 57 residential rates. The rates are of three types:

1) standard residential electric rates,
2) all-electric rates, typically available only if the household uses electricity for both space and water heating, and
3) electric water heating rates. Sometimes water heaters are separately metered and sometimes they are not. Even if they are not, however, ownership of an electric water heater may permit the household to purchase <u>all</u> electricity under a special rate! We have included in our sample several observations where this was the case. We have excluded, however, observations on consumption <u>solely</u> for the purpose of water heating. If demand for electricity for this purpose varies relatively less than does demand for all other purposes then our dependent variable will overstate slightly the variation in consumption.

Our sample contains 39 standard, 16 all-electric, and two water-rate observations. The variables are constructed as follows: (A complete list of the final data sources is given in the appendix.)

Prices and Quantity

For each rate schedule we calculate average monthly consumption in kilowatt hours (KWh) for 1975. We can then use the rate schedule to determine the marginal price and value of all infra-marginal charges, which we call the "demand fee." The demand fee is equal to the total electric bill less less the quantity (marginal price times KWh). In cases where rates were changed sometime during 1975, we use weighted averages of the old and new rates, where the weights are the number of weeks each was in force.

Fuel Adjustment Charges

Utilities can vary the retail price of electricity to their residential customers without going through any formal rate change proceedings by means of "fuel adjustment charges." Such charges are intended to permit utilities to "pass on to the consumer" changes in the cost of fuel to the utilities without constantly adjusting rates. Especially in recent years, a substantial portion of retail price variation is due to variation in the fuel adjustment charges, rather than in the rates themselves. The fuel adjustment is, in every case, a fee in cents per KWh applied to every KWh consumed. Hence it enters both the marginal price and the demand fee. We use, for each utility, the fuel adjustment charge in force on January 1, 1975.

The means and standard deviations of the quantity, marginal price, and demand fee observations are as follows:

	Mean	Standard Deviation
KWh (Kilowatt hours/ month/household)	900.04	714.39
PM (¢/KWh)	3.90	.64
FEE ($)	4.74	2.36

One is struck by how low the implicit demand fee is. Even when looking only at the subset corresponding to all-electric homes, the average monthly figure is only $6.22. It is not surprising when we find that this variable appears to have little effect on consumption. The mean marginal price for standard rates is 4.014 ¢/KWh; on all-electric rates it is only 3.586 ¢/KWh.

Income

The Internal Revenue Service has published the 1969 adjusted gross income for each 5-digit zip code service area in the United States. It is easy to establish the zip code makeup of each electric utility district, and so arrive at a per household average monthly income for each district. It would be better to have more recent data, but Congress ordered the IRS to cease publishing such data in the early 1970's, on privacy grounds. As a suggestion to its accuracy, the simple correlation between median family income in 23 Massachusetts counties and SMSA's in 1969 and 1975 is just over .88. While not perfect, this is perhaps as good an income cross-section as one is likely to get. The mean and standard deviation (1975 dollars) are $1167.37 and $319.96 respectively.

Appliance Stocks

A mail survey taken by the Federal government (Project Conserve) in Massachusetts in Spring, 1976, provides data on appliance ownership, housing characteristics, etc., for single family dwellings. There were 136,000 responses received, though for purposes of this study we use a random sub-sample of 29,445. We assign each response to an electric utility district and calculate for each district per single family dwelling ownership of the five electric appliances listed below.

per SFD ownership of:	Mean	Standard Deviation
electric space heat	.05	.03
electric water heat	.23	.09
electric stove	.63	.17
color TV	.80	.08
frost-free refrigerator	.74	.06

Per single family dwelling is not the same as per household, but there is no obvious way to do better. In any case, we also include the percentage of customers living in single family dwellings as an explanatory variable in regression equations.

One peculiarity worth noting here is that per SFD ownership of four of the above five electric appliances have negative simple correlation coefficients with income, electric stoves being the exception. The simple r associated with color TV sets, -.40, is the largest and most surprising.

Gas Price

The final variable is the average residential price of natural gas. This was constructed for each electric utility district from data reported by each of the nineteen gas utilities which serve the Commonwealth. Its mean is \$3.15/MCF with a standard deviation of \$.29.

IV. Empirical Results

Short Run

Various forms for the demand equation were tried. We settled on a simple logarithmic form, using single-equation ordinary least squares. The estimated demand equation is (t-statistics in parentheses):

$$\text{KWh} = \underset{}{3.95} - \underset{(.40)}{.08\ \text{PM}} + \underset{(2.28)}{.32\ \text{Y}} + \underset{(1.44)}{.13\ \text{PSFD}} + \underset{(19.33)}{1.37\ \text{HEAT}}$$

$$+ \underset{(3.73)}{.60\ \text{WATER}} + \underset{(1.70)}{.19\ \text{STOVE}} + \underset{(.22)}{.09\ \text{COLOR TV}} - \underset{(1.39)}{.66\ \text{FROST}}$$

$R^2 = .9132$

SER = .2153

where all variables are in logs and

KWh = kilowatt hours consumed per month per household

PM = marginal price of electricity

Y = income

PSFD = percentage of customers living in single family dwellings

HEAT = a dummy variable, equal to one if consumption is on an all-electric rate and zero otherwise

WATER = a dummy variable, equal to one if consumption is on a rate discounted for owners of electric water heaters and zero otherwise

STOVE = per single family dwelling ownership of electric stoves

COLOR TV = per single family dwelling ownership of color televisions

FROST = per single family dwelling ownership of frost-free refrigerators.

In various regressions the demand fee was never a significant explainer of consumption. Nor was its coefficient usually different from minus one times that of income, though this was a result more of a large standard error than of anything else. So we simply subtract the fee from gross income; the resulting net income is the explanatory variable we use in all subsequent regressions.

The short run price elasticity is very small - less than .1 - and not significantly different from zero. This is not surprising given that we are holding household electric appliance stocks constant. The income elasticity - .32 - is also reasonable in this equation. As expected, electricity consumption by households in single family dwellings is, ceberis peribus, higher than for households in multiple family dwellings.

The HEAT and WATER variables turn out to be critical. If they are deleted the explanatory power of the regression falls dramatically. More importantly, they strongly affect the coefficients of other variables. If they are deleted the coefficients of PM and of Y reverse sign, implying positive price elasticity and negative income elasticity. If we then enter per household ownership of electric heat and electric water heat as alternative explanatory variables, they do not do nearly so good a job as the original variables. Most of the variation remains unaccounted for, and an unbelievably large price elasticity of -1.33 is implied. It is not surprising that these latter alternatives do not perform nearly so well since it is much more difficult to match up variation in these with the proper rate schedule. Indeed, we find a negative partial correlation between per household electric heat and our HEAT dummy.

Other household appliance stocks are less important. Deleting various of them only marginally reduces R^2, and does not alter other regression coefficients. Furthermore, the negative coefficient of FROST was an anomaly which showed up in almost all of the regressions. We have no explanation for this.

Note that we exclude the price of oil and natural gas from these regression equations. In the short run there is little or no scope for substitution into alternative fuels. We also exclude temperature since variation in this variable would mean little with our sample. We also exclude other characteristics of the housing stock. Project Conserve does offer some data in this area; but the analysis of this data is a topic in its own right. Given our high R^2 there is little to be gained by forcing long variable lists into this equation.

Examination of the residuals indicated no patterns. For 52 or the 57 observations "predicted" consumption falls in the same rate block as actual consumption. Under the hypothesis of no simultaneity bias, the residuals are BLUE estimators for the errors. The fact that most residuals are small enough not to push consumption into another rate block is a hopeful indicator that actual simultaneity bias is slight.

Long Run

Our long run results are generally weaker than the short run results just discussed. With a few exceptions, we are not able convincingly to explain variation in appliance-type shares with prices and incomes alone. There are, we believe, two reasons for this.

First, several variables which we would expect to have an effect on appliance choice are essentially invariant within Massachusetts. There is no believable reason to think that there are systematic differences in asset rental prices across the Commonwealth. Similarly, the retail price of oil shows little cross-sectional variation, as one expects in a highly competetive market. Consequently, whatever variation one does observe in appliance shares is largely due to "other factors" which this model is poorly equipped to explain.

Secondly, the calculation of appliance shares from data on the outstanding stock obscures the fact that these shares have changed dramatically in recent years. For example, after 1973 shortages of natural gas developed in Massachusetts. New gas hook-ups were severely curtailed - eliminated in many areas. This followed a period during which gas utilities had encouraged gas appliance use.

Similarly, the history of construction of all-electric homes shows wide and rapid swings. After the oil price increases of 1973, construction of all-electric homes virtually ceased. The following table illustrates the difference in fuel shares between the 1974 stock of homes and the 1970-1974 flow of new housing. (This data is for the Boston SMSA only.)

Table 1

Home Heating Fuel Shares

	1974 Stock	1970-1974 New Construction
Fuel Oil	66.8%	24.9%
Utility Gas	27.8%	34.7%
Electricity	5.0%	40.1%
All other	.4%	.3%

Cooking Fuel Shares

	1974 Stock	1970-1974 New Construction
Utility Gas	57.8%	25.4%
Electricity	40.6%	73.5%
Bottle Gas	1.3%	1.1%
All other	.3%	-

Source: See appendix.

To be sure, there is substantial variation in each of the dependent variables.

		Mean	Standard Deviation
space heat	$\log \left({}^{ME}/_{MO}\right)$: R1	-2.44	.87
	$\log \left({}^{ME}/_{MO}\right)$: R2	-.83	.85
water heat	$\log \left({}^{ME}/_{MO}\right)$: R3	-.45	.56
	$\log \left({}^{ME}/_{MO}\right)$: R4	-.09	.98
cooking	$\log \left({}^{ME}/_{MG}\right)$: R5	.68	.99

More interesting is the pattern of simple correlations:

	R1	R2	R3	R4	R5
R1		.12	-.09	.21	-.25
R2			.24	.90	-.73
R3				.37	.27
R4					-.90

The high positive correlation between R4 and R2 and negative correlation between R4 and R5 tell us that whenever natural gas is used for <u>any</u> major appliance it will probably be used for all. In contrast, note the negative correlation between R1 and R3, and between R1 and R5. No such presumption exists for electricity.

The individual regressions are as follows:

(t-statistics in parentheses)

Space Heating

$$\text{1)}\quad \log(\text{elec./oil}) = 1.94 - \underset{(4.90)}{.83\ PM} - \underset{(1.71)}{.08\ FEE} - \underset{(3.25)}{.001\ Y} + \underset{(.34)}{.115\ PG}$$

R^2 = .3758

SER = .7200

$$\text{2)}\quad \log(\text{gas/oil}) = -2.10 - \underset{(.33)}{.07\ PM} + \underset{(1.35)}{.07\ FEE} - \underset{(.35)}{.0001\ Y} + \underset{(1.03)}{.42\ PG}$$

R^2 = .0728

SER = .8606

PG is the price of natural gas; all other variables are as previously defined.

Equation 1) indicates a price elasticity of the probability of electricity's being chosen of -.83, a reasonable number. The other coefficients are also reasonable though the small, significant negative income effect is odd. It could be explained if all electric homes were built in lower rather than higher income areas after 1969.

Other Appliances

Regression results for water heating and cooking fuel were not very successful. For the convenience of the reader they are reproduced here.

Water Heating:

$$\log\left(\frac{\text{elec.}}{\text{oil}}\right) = -2.33 + \underset{(.23)}{.03\ PM} + \underset{(.21)}{.007\ FEE} - \underset{(.81)}{.0002\ Y} + \underset{(2.37)}{.62\ PG}$$

R^2 = .1226

SER = .5467

$$\log(\text{gas/oil}) = -1.12 - \underset{(.87)}{.20\ PM} + \underset{(.51)}{.03\ FEE} - \underset{(.45)}{.002\ Y} + \underset{(1.39)}{.66\ PG}$$

$R^2 = .0606$
SER = .9916

<u>Cooking Fuel</u>:

$$\log(\text{elec./gas}) = .53 + \underset{(1.14)}{.26\ PM} - \underset{(.23)}{.01\ FEE} + \underset{(1.96)}{.0008\ Y} - \underset{(1.19)}{.56\ PG}$$

$R^2 = .1001$
SER = .9842

V. Note on "Lifeline" Rates

Recently there has been a great deal of interest in re-structuring electricity rates for social purposes. A frequent proposal is the so-called "lifeline" electricity rate schedule. Such a schedule would lower the cost to the consumer of using relatively small amounts of energy by reducing the price charged for some monthly base quantity. One way of accomplishing this would be by inverting rate schedules, so that the marginal price rose rather than fell with increased consumption. Indeed, inverting electric rate schedules has often been proposed on efficiency grounds as well. But it is equity considerations, rather than efficiency, which motivate the "lifeline" proposals.

Two justifications have typically been advanced for "lifeline" pricing; we shall look at each. The first is that a moderate amount of electric energy is necessary to a decent standard of living, and that society should be willing to provide this minimum amount of energy at very low cost to all of its members. This is a logical justification for "lifeline" rates. But it should be pointed out that it makes no mention of redistributing income from upper to lower income consumers.

The second justification is that it would be desirable to reduce the burden of electric bills to the poor. Since it is recognized that utilities cannot identify and/or adopt preferential pricing toward the poor *per se*, it is proposed that *all* customers be guaranteed a moderate amount of electricity at very low cost. Unlike the first justification, which is always valid, this argument is valid only under certain empirical conditions, which may or may not be met in any given electric utility district. Only if consumption and income are positively correlated within the utility district will the desired transfer take place; otherwise the burden will be shifted toward the poor.[6] A positive income elasticity of demand does not guarantee this, since this partial effect may easily be offset by the other factors which determine electricity consumption.

Ideally we would wish to know the correlation between KWh and Y within every electric utility district. The tables we reproduce below, however, are calculated across utility districts. For interest, we include the simple correlation of income with the marginal price and demand fee.

Table 2

Simple Correlation Coefficients: Standard Rates

	Income	Marginal Price	Demand Fee
Marginal Price	-.20		
Demand Fee	.14	-.32	
KWh consumed	.51	-.07	.13

Simple Correlation Coefficients: All-Electric Rates

	Income	Marginal Price	Demand Fee
Marginal Price	-.19		
Demand Fee	-.05	-.38	
KWh consumed	.37	-.18	.57

Income and consumption are, in fact, positively correlated, so at least the net direction of the income re-distribution is progressive. With these relatively low correlations, however, the efficiency of such a scheme is questionable.

VI. Conclusions

We use ordinary least square estimates of a simple logarithmic short run demand function and of a logit model for long run appliance choice. We believe that the data used is superior in both accuracy and variation to that employed in most dis-aggregated studies of electricity demand. We recognize the problem of simultaneity bias, but argue that it is minor in our sample.

We conclude that in the short run the own price elasticity of demand for electricity is very small - only about -.08. The income elasticity of demand is about .32. Both of these estimates are reasonable when one holds appliance stocks constant.

The demand fee associated with declining block rates is a much smaller part of the total electricity bill than was perhaps thought. It does not appear to influence electricity consumption significantly in the short run, though it does have some effect on long run choice.

The most important consumer durable influencing electricity consumption is, as might be expected, electric space heating. Long run demand for this durable good is significantly responsive to changes in the retail price of electricity, both in the marginal price and in the demand fee. The elasticity with respect to marginal price is about -.83. (It should be pointed out again that Massachusetts owners of all-electric homes pay, on average, a lower marginal price than do consumers on standard rates; and only a slightly larger demand fee.) The cross elasticity of demand for electric space heat with respect to the price of natural gas is .12.

The logit results are weakened since we are unable to capture variation in the price of fuel oil, which is New England's most important heating fuel. Also, regression analysis does not reveal the importance of natural gas shortages in recent years.

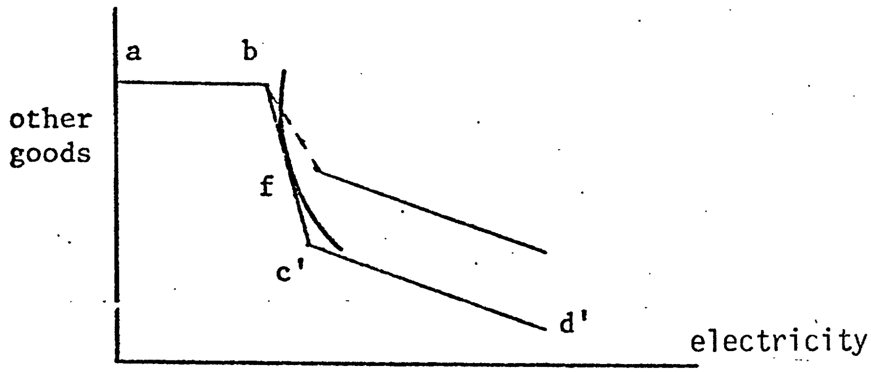
Finally, appliances such as color televisions and frost free refrigerators seem neither to be major explainers of residential consumption, nor particularly responsive to electricity price changes.

With respect to "lifeline" electric pricing, it appears that the net effect of such rates would be a slight reduction in the share of the burden borne by lower income groups. The correlation is far from perfect, however, and there may exist many low income sub-groups which would end up with larger shares of the burden.

Footnotes

1. Related studies which may be of interest to the reader include (Acton, Mitchell, and Mowill, 1976) and (Levy, 1973).

2. It is possible that the consumer will move to a point like f below, on a different portion of the rate schedule. For the moment we assume that this "switching" does not occur.



3. See, for example, (Rao and Miller, 1971, pp. 195-197). The derivation of this expression actually depends on expressing quantity supplied as a single-valued function of price and other variables. We noted above this is not the case with declining block supply schedules. The critical feature of negative correlation between errors in the demand equation and marginal price remains, however. For these purposes no violence is done to the argument by "pretending" that the supply schedule is smooth.

4. Fisher and Kaysen conclude that the effects of energy prices are negligible (except for water heaters and ranges). Chapman et. al. find a significant effect using an aggretate appliance price index as an explanatory variable, but it is unclear why such an index should show cross-section variation; or if it is even appropriate in a regression

where the dependent variable is electricity consumption. Wilson finds that the price of electricity is generally a significant factor explaining appliance ownership.

5. This approach is discussed in (Hartman and Hollyer). In particular, see their discussion of the issue of equality of corss elasticity constraints in the Appendix.

6. Of course, even if the correlation is of the correct sign, still this may be an inefficient mechanism for redistributing income. See (Berg and Roth, 1976)

Appendix: Data Sources

Income: Internal Revenue Service adjusted gross income by 5-digit zip code, aggregated to the appropriate electric utility district. See U.S. I.R.S., "Federal Individual Income Tax Return Data for Each 5-Digit Zip Code Area in Massachusetts: 1969" N.T.I.S. Report # PB 209 321 (May, 1972).

Price of electricity, expenditure on electricity, consumption of electricity, fuel adjustment charges: Electric utility annual reports on file with the office of the Massachusetts Department of Public Utilities, and the U.S. Federal Power Commission, National Electric Rate Book, Massachusetts issues for August 1976 and January 1975.

Appliance Stocks: Project Conserve details ownership of the various assets for single family dwellings by 5-digit zip code area. These are aggregated to the appropriate electric utility district. Project Conserve data was supplied by the New England Energy Management Information System at the M.I.T. Energy Lab.

Price of Gas: Average price for each of the neneteen gas supplying utilities in Massachusetts, from data on file with the state Department of Public Utilities. The geographic composition of each gas utility is taken from the New England Gas Association, Membership and Statistical Directory: 1975, Boston (December 1975). Note that there is a single, small supplier of gas, the Athol Gas Co., which does not belong to the New England Gas Association.

Percentage of households which are single family dwellings, number of households (for weighting purposes): "Detailed Housing Characteristics" of the 1970 Census of Housing, U.S. Bureau of the Census.

Data on fuel shares for the Boston SMSA (Table 1) is from the U.S.

Bureau of the Census, Annual Housing Survey: 1974, "Housing Characteristics for the Boston SMSA," H-170-74-3 (September 1976).

All data is for 1975 except for the Appliance Stocks, which come from a survey taken in April-June 1976; income, which is for 1969; and the demographic variables, which are from the 1970 Census. Given the unusual detail with which we observe these variables, (aggregating from zip code areas and towns to electric utility districts) it is unlikely that this introduces any significant bias.

References

1. Acton, Jan, Bridger Mitchell, and Ragnhild Mowill, "Residential Demand for Electricity in Los Angeles: An Econometric Study of Disaggregated Data," Rand Report # R-1899-NSF, September, 1976.

2. Berg, Sanford V. and William E. Roth, "Some Remarks on Residential Electricity Consumption and Social Rate Restructuring," Bell Journal of Economics, 7 No. 2 (Autumn 1976) 690-698.

3. Fisher, Franklin M. and Carl Kaysen, A Study in Econometrics: The Demand for Electricity in the United States, Amsterdam, North-Holland Publishing Company, 1962.

4. Hartman, Raymond S. and Mark R. Hollyer, "An Examination of the Use of Probability Modeling for the Analysis of Interfuel Substitution in Residential Fuel Demand," mimeo.

5. Levy, Paul F., The Residential Demand for Electricity in New England, M.I.T. Energy Laboratory Report # MIT-EL 73-017, November, 1973.

6. Mount, T.D., L.D. Chapman, and T.J. Tyrrell, "Electricity Demand in the United States: An Econometric Analysis," in Energy, Michael S. Macrakis, ed., Cambridge, Massachusetts, the M.I.T. Press, 1974.

7. Rao, Potluri and Roger LeRoy Miller, Applied Econometrics, Belmont, California, Wadsworth Publishing Company, Inc., 1971.

8. Taylor, Lester D., "The Demand for Electricity: A Survey," Bell Journal of Economics, 6 No. 1 (Spring 1975) 74-110.

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