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INTERPRETING DEMAND ELASTICITIES: HAS THE DEMAND FOR RESIDENTIAL ELECTRICITY CHANGED? IF SO, WHY AND SO WHAT?

Thomas H. Stevens and Gail Adams

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Department of Agricultural and Resource Economics
Draper Hall
University of Massachusetts
Amherst, MA 01003

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Introduction:

Electric power plant construction requires ten or more years and the investment decisions made now will greatly influence both the cost of power and the generating options available for the future. Accurate demand forecasts are therefore becoming increasingly important, but at the same time forecast accuracy appears to be decreasing.

During the 1950's and 1960's most demand forecasts were based upon judgement, trend line extrapolation, or simple correlation. The resulting forecasts made for the pre-oil embargo era proved to be very accurate. For example, Ascher (1978), found a median error of 3.5 and 6.0 percent for a random sample of pre embargo 5 and 10 year electric demand forecasts respectively. Moreover, methodology appeared to be of secondary importance for forecast accuracy (Ascher, 1978). One reason for this is that energy markets were relatively stable throughout the 1960's, and most factors thought to influence demand trended together over time. The real price of electricity, for example, fell rather consistently while real incomes continued to rise.

The post embargo era has proven to be much less stable and most of the five year forecasts which were prepared between 1970 and 1973 yielded enormous error (see Ascher, 1978). Forecasters responded by employing increasingly sophisticated techniques, but the forecasts prepared in the mid to late 1970's for 1980 and 1985 target dates have now also proven to be quite inaccurate; (see Table 1 and Figure 1); and debate has begun to focus upon whether or not structural changes in demand have occurred. However, very little empirical evidence has been presented.

TABLE 1
Selected Electric Power Generating Forecasts and Forecast Error [a]

STUDY	YEAR*	PROJECTED ELECTRIC GENERATION TKWH 1980	1985***	PERCENT FORECAST ERROR 1980	1985***
Mount, et al.	1973	2.37-2.92	2.55-3.70	3-26	5-53
OCED	1974	3.04	4.21	33	74
Livermore	1974	2.60	3.42	14	41
FPC	1974	2.66	3.56	16	47
A.D. Little	1974	2.72	3.72	19	54
Bureau of Mines	1975	2.77	3.96	21	64
Data Resources	1975	---	3.38	--	40
Westinghouse	1975	2.52	3.21	10	33
Oak Ridge	1975	2.53	3.25	10.5	34
ERDA	1975	3.07	3.89	34	61
FEA	1976	2.57	3.35	12	38
Joskow and Baughman	1976	2.51	3.22	9.6	33
Chern, et al.	1976**	4.1%(1973)		7	--
FEA	1976**	5.4%(1974)		11	--
Edison Electric Institute	1976**	5.4%(1974)		11	--
Chern, Just, et al.	1978**	4.6%(1974)		6.5	--
Baughman, Joskow, Kumat	1979	2.43	3.08	6	27

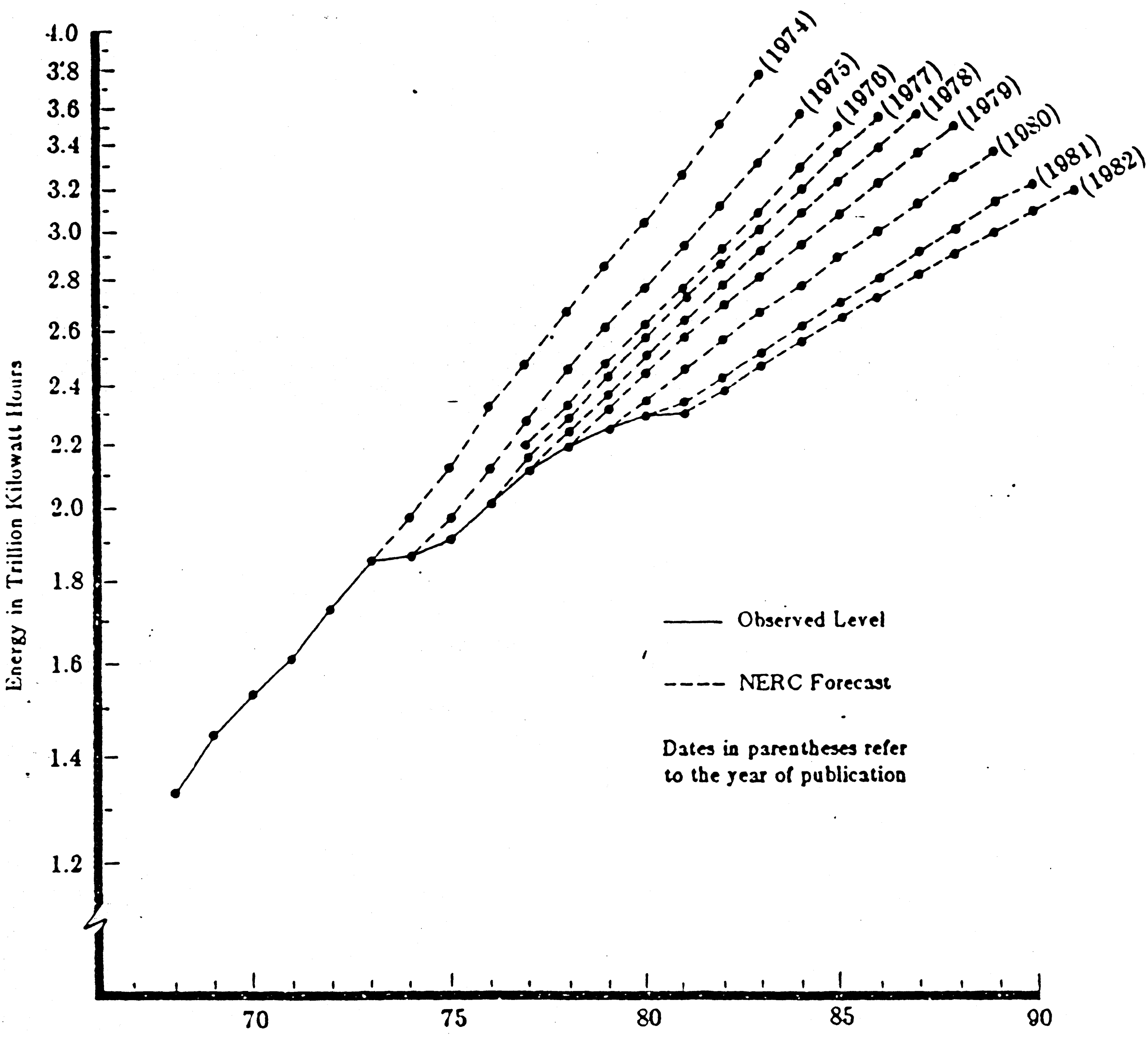
(a)Source: Ascher (1978)
Actual 1974 generation = 1.87 TKWH
Actual 1980 generation = 2.29 TKWH
Actual 1984 generation = 2.42 TKWH (est)

*Year that forecast was published.
**Annual growth rate from base year in parentheses.
***1984 actual generation used to calculate percentage error.

Figure 1

FORECASTS OF ELECTRIC ENERGY NEEDS IN THE UNITED STATES

PUBLISHED BY THE NATIONAL ELECTRIC REALIBILITY COUNCILS (1974-82)



Year

In this paper we report results suggesting that the price elasticity of the residential demand for electricity in New England has changed. Several reasons for this are discussed and in particular we investigate whether or not demand is asymmetric with respect to price. That is, we hypothesize that people may have responded differently to the recent electricity price increase than they did to the price decreases of similar magnitude prior to the 1973 "energy crisis". We then examine whether or not this is an important factor for forecast accuracy.

The Evidence:

Determination of the length of run presents a major problem both for detection and interpretation of structural change in electricity demand. Electricity is consumed in conjunction with a stock of durable appliances, and long run own-price elasticities are therefore expected to be larger than their short-run counterparts, *ceteris paribus*. That is, changes in price will influence the rate of appliance utilization in the short-run. In the long run the type, size, and efficiency of the appliance stock can also be altered.

Neoclassical consumer demand theory provides relatively little guidance to distinguish between lengths of run, and several different approaches have been used in econometric analysis.[1] The simplest involves estimating a static reduced form demand model with quantity of electricity consumed regressed against its price, the price of substitute fuels, consumer income, the stock (or saturation) of appliances, and a vector of other variables such as climate, etc. This specification yields results which are conditioned upon the observed stock of applicances. The distinction between lengths of run can only be inferred, either from the type of data used or by employing a simple partial adjustment mechanism (a distributed lag for example).

In the former case, models estimated from cross-sectional data have often been given a long-run interpretation while analyses undertaken with time-series data are normally considered to produce short-run results. Since the length of run is defined in terms of variable and fixed factors, cross-sectional data are considered to produce long-run results because households possess different fixed assets; therefore they are presumably in different stages of a secular process of adjustment. On the other hand, time series of observations are assumed to reflect short run fluctuations in behavior. (See Adams, 1984).

This distinction between long-run and short-run demand can however, be misleading, and careful interpretation of the results of statistical inference is necessary. The use of static reduced form models which pool time-series and cross-sectional data reinforces the need for careful model interpretation. Whether results are considered to be long run or short run depends on conditions in the market under analysis and it now appears that the type of data used cannot be relied upon to define long-run and short-run electricity demand. (See Willis, 1975 and Bohi and Zimmerman, 1984). Hence, it is necessary to model this distinction explicitly. Failure to do so precludes our ability to detect or to isolate the cause of structural change.

Two alternatives appear to be feasible given the constraints imposed by most data sources. A partial adjustment mechanism can be assumed or structural demand models can be specified in which both the use of electricity and the demand for electrical appliances are modeled. The latter approach is clearly preferred, and was used in this study.

The short-run demand for electricity was expressed in terms of real electricity price, real income, the appliance stock, and other relevant variables. Models of the following type were then estimated:

$$Q_{it} = f(P_{it}, T_t, Y_{it}, D_j, K_{it})$$

where:

Q_{it} = Quantity of electricity demanded per customer in time t in utility i.

P_{it} = Average price of electricity in utility i in time t, deflated by the consumer price index.

Y_{it} = Average yearly household income in each utilties service area (deflated)

T_t = An index designating the year.

D_j = Dummy variable for each state.

K_{it} = Index of the saturation of electrical appliances in each utility for each year.

j = 1,...,6, states.

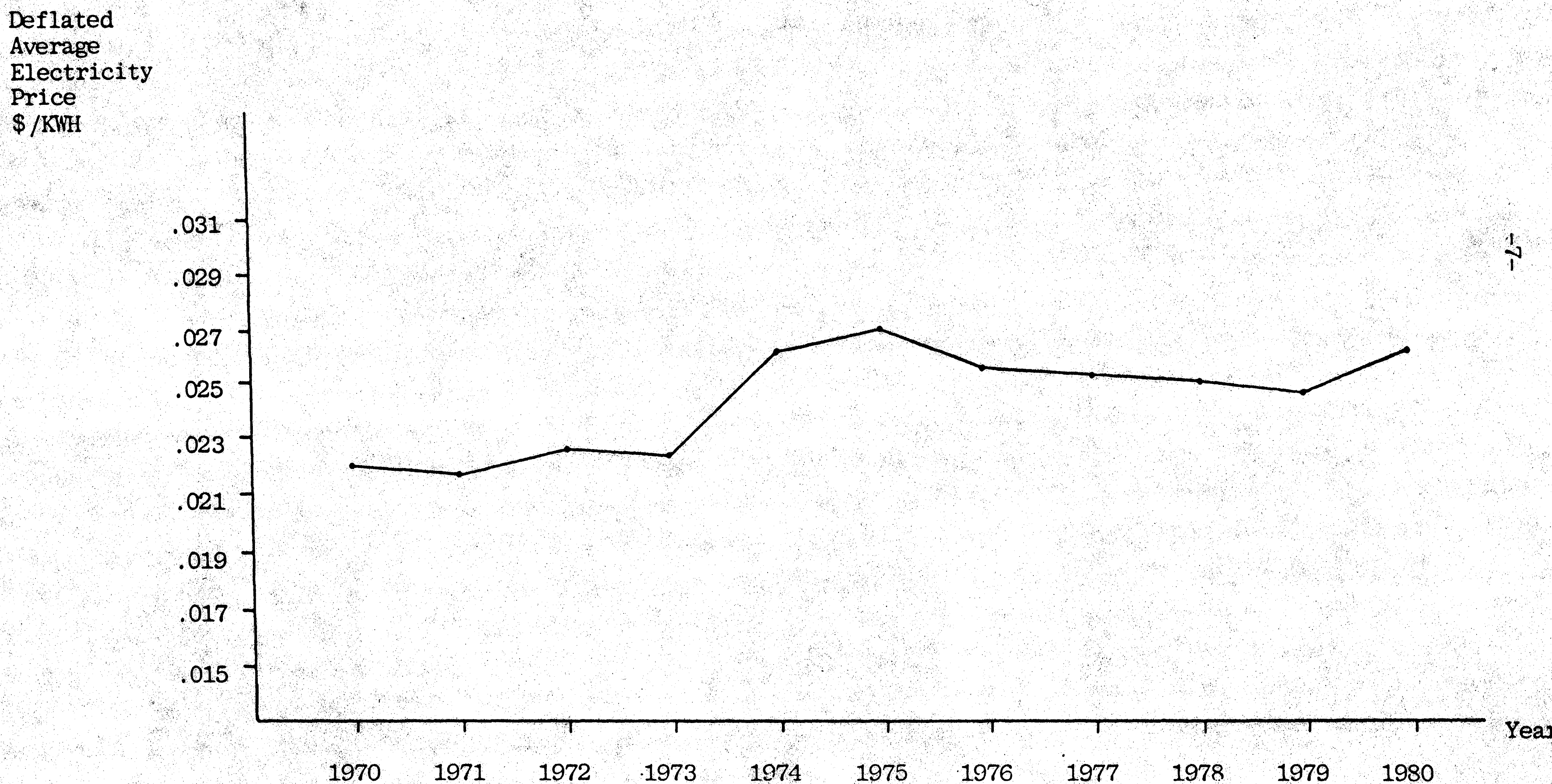
t = 1,...12, time periods.

i = 1,...22, utility companies.

The data included annual observations on 22 electrical utilities in the six New England states for 1970-1981.[2] This time period includes both the 1973 OPEC oil embargo and the 1979 "oil shortage". Price behavior was unstable during much of this time with real price rising sharply in 1974, (see Figure 2).

Figure 2

AVERAGE ELECTRIC PRICES, NEW ENGLAND (1967 DOLLARS)



Long-run electricity demand models require analysis of the demand for the appliance stock. The demand for K was expressed as:

$$K_{it} = g(P_{it}, R_t, API_t, D_j, Y_{it})$$

where:

R_t = The real rate of interest in time t.

API_t = The appliance price index in time t, and all other variables are as defined above. The long-run elasticities were then calculated by the procedure suggested by McFadden, et al (1977).

Short-run and long-run own-price elasticity estimates are summarized in Table 2. In all cases the long-run values are larger than their short-run counterparts, and the estimates for 1976-1981 are lower than those for 1970-1975. (The Chow Test indicated that the models for the two time periods could not be pooled.) That is, the response of demand to price appears to have changed between 70-75 and 76-81 both in the short and the long run.[3]

Sensitivity:

As noted by Leamer, (1983 p.43) "almost all inferences from economic data are fragile..." and "...we need to be shown that minor changes in the list of variables do not fundamentally alter the conclusions, nor does a slight reweighting of observations, nor correction for dependence among observations, etc..." (1985, p. 308). In other words it is important to examine the sensitivity of our results; are they unique to New England? To model specification, to level of aggregation?

The range of results from alternative model specifications are presented in Table 3. Data limitations precluded the estimation of structural demand models for electric heat customers or for data aggregated to the state level. Reduced form models with a lagged adjustment mechanism were used instead. The range of elasticity values for New England, for any particular data type, time frame and length of run were derived by using different functional forms and definition of the price variable (current versus lagged average price). The values for the nation as a whole were taken from two previous studies. Yang (1978) used both marginal and average price models and found U.S. residential electricity consumption to have become much less responsive to price during the embargo than before. Young, Stevens and Willis (1983) report a similar

Table 2. Summary of Own Price Elasticity Estimates.

		Elasticities	
Region	Time Period	Short Run	Long-Run
New England	70-75	-.558	-.990
	76-81	-.320	-.46
Northern New England	70-75	-.468	x
	76-81	-.350	x
Southern New England	70-75	-.393	-1.085
	76-81	-.390	- .695

x = not statistically signicant at the 90% level.

Table 3. Range of Own-Price Elasticity Estimates

Data Type Region Study	Time Period	Model Type: Structural SR	Structural LR	Reduced Form SR	Reduced Form LR
I. Utility Level.					
New England All Customers	70-75	-.60 to -.53	-1.0 to -.98	-.11 to -.09	-2.75 to -1.05
	76-81	-.41 to -.22	-.48 to -.44	-.29 to -.18	-.82 to -.43
Northern New England All Customers	70-75	-.51 to -.46	-------	-.53 to -.12	-5.9 to -1.4
	76-81	-.36 to -.34	-------	-.33 to -.29	-.76 to -.64
Southern New England All Customers	70-75	-.53 to -.28	-1.18 to -.99	-.08 to +.10	-5.0 to -1.43
	76-81	-.39	-.73 to -.66	-.33	-.61
New England Electric Heat Customers	67-74			-.94 to -.41	-1.42 to -.61
	75-81			-.24 to -.23	-.34 to -.33
Northern New England Electric Heat Customers	67-74			-.67 to -.50	-.92 to -.75
	75-81			-.23 to -.22	-.35 to -.31
Southern New England Electric Heat Customers.	67-74			-1.6 to -.80	-2.03 to -.99
	75-81			-.44 to -.43	-.60 to -.58
II. State Level.					
New England All Customers	70-75			-.25 to -.24	
	76-81			-.10 to -.06	
Northern New England All Customers	70-75			-.57 to -.18	
	76-81			-.13 to -.04	
Southern New England All Customers	70-75			-.40 to -.09	
	76-81			-.05 to -.15	
III. National Level					
Time Series All Customers Young, Stevens, Willis, (1983)	47-74			-.93 to -.86	
	74-77			-.48 to -.38	
Pooled cross-section Time Series All Customers Yang (1978)	62-72			-1.075 to -.74	
	73-75			- .57 to -.295	

pattern while both McRae and Webster and Kenney and Kirschner report a decrease in the own price elasticity of electricity demand in the industrial sector. (See Bohi and Zimmerman, 1984). We therefore conclude that there is a good deal of evidence supporting the notion that demand has indeed changed.

Reasons For Changes in Price Elasticities

There are several reasons why the price elasticity of demand may have changed in both the short and long run. At least two factors could have resulted in larger elasticities being observed since the embargo. First, new appliances have become relatively more energy efficient over time but these changes were not modeled because of insufficient data.[4] As a result, own price elasticities might be biased upward. At each price, kwh consumed will likely be less as efficiencies increase and as a result elasticities might *appear* to have increased between the pre and post embargo periods. Second, own price elasticities are expected to increase as electricity becomes a larger proportion of total household expenditures; *ceteris paribus*.

There are, however, many more arguments which support our empirical findings. These are all based upon the notion that real electricity prices have tended to increase since 1973 (See Figure 2) and that demand should be *less elastic* in periods of rising price, all else equal. The first argument is based upon the theory of habit formation, and suggests the possibility of asymmetry in short-run demand response. In particular, habits related to the use of appliances (e.g., dishwashers and electric lights) developed during periods of falling price may not be quickly abandoned when prices rise. If so, the observed short-run response to rising prices will be less than the response associated with a price decline of equivalent magnitude.[5]

Second, and creating the possibility of price asymmetries in the long-run, is the notion that people probably purchased many electrical appliances when real electricity prices were relatively low or falling and real incomes were rising. These appliances now form part of the standard of living, which people may have become reluctant to change. As electricity prices rise, people will substitute alternatively fueled appliances when available, feasible, and economical. However, most people will probably be unwilling to sacrifice color television sets, dishwashers, self-cleaning ovens, etc., perhaps first purchased during the pre-embargo period of falling real prices. Scitovsky (1978) labeled this unwillingness to relinquish so-called luxury durables "addiction asymmetry," and it should not be confused with technological and institutional rigidities associated with appliance stocks (i.e., asset fixity or investment irreversibilities), which prevent the consumer from immediately making the desired response to price changes.

Third, the initial shock and uncertainty, and the relatively sudden sharp price jumps created by the 1973 oil embargo may have been viewed by many consumers as temporary. Also, the simultaneous emergence of widespread economic uncertainty and rapidly rising interest rates, coupled with the lack of readily accessible second-hand markets, may have motivated consumers to postpone decisions about the replacement or purchase of new, more efficient appliances. As a result, demand since the embargo could appear to be more price inelastic in the "long-run" than before. This interpretation is closely associated with the distinction between lengths of run and with asset fixity. That is, the observed behavior during the post-embargo era may have been relatively more representative of "short run" behavior even though appliance stocks were allowed to vary in the demand models. In other words, the long run may have become "longer" if there had been an increase in the effective degree of asset fixity.

Testing For Asymmetry:

The estimated differences in "short" run elasticities between the pre and post embargo periods may be due to the force of habit. However, the differences in long run elasticities can result from addiction asymmetry, changes in the relative degree of asset fixity or some combination of both. It is important to distinguish between these possibilities because of the need for improved forecast accuracy and because each hold different implications for policy. For example, relatively little can be done to break an "addiction asymmetry" phenomenon without a major change in the structure of society's values. Disaccumulation is not currently viewed as a status symbol in most segments of our society. Therefore, effective policy measures might include mandated energy efficiency standards.[6]

On the other hand, increases in the degree of asset fixity require policy initiatives to speed long-run adjustment processes by removing institutional impediments to the replacement of durables. Such initiatives may take the form of tax incentives and recycling programs which encourage consumers to replace inefficient durables.

We have shown that changes in the price elasticity of demand have occurred both in the short and long run. The extent to which this is due to asymmetry (habit in short-run and addiction in the long-run), can be examined in several ways. First, the data can be subdivided into two groups; the first consisting of the years of falling real price with the second comprised of the years of rising prices. Separate demand models for each group can then be estimated and the results compared for both the short and long run. This was, in essence, the approach used in the analysis above.

An alternative test for short-run asymmetry can be performed by estimating ratchet type demand models. The simplest ratchet model allows the demand curve be kinked at the prevailing price, no matter what the history of price variation has been. An alternative ratchet specification allows the demand curve to become kinked when prices reach unprecedented low levels. Ratchet models were used by Young, Stevens and Willis (1983) who found evidence of asymmetry of short-run consumer response to both price and income: the rising short-run price elasticity was estimated to be approximately half the size of the falling short-run price elasticity.

Unfortunately, none of these procedures can isolate the effect of addiction asymmetry in the long-run from that due to changes in the degree asset fixity at either the national or utility levels. This is partly because increases in real electricity prices have occurred simultaneously with increases in interest rates, economic uncertainty, etc. and the resulting multicollinarity makes it virtually impossible to isolate the contribution of each. However, several conclusions can still be drawn from the evidence presented here.

Conclusions

We have demonstrated that residential electricity demand has become less responsive to price since the embargo. Both the short and long-run price elasticities for the recent period of rising real prices appear to be smaller than those associated with the earlier periods of stable or falling real prices. Previous studies have failed to examine the types of responses which can result from habit in the short-run and addiction or investment irreversibility to a particular lifestyle in the long run. Although we were unable to make the latter distinction empirically, our findings are of potential importance for futhering the study and understanding of consumer behavior.

The importance of our results for forecast accuracy are, however, less clear. There are two major sources of errors associated with econometrically based forecasts ; (1) biased or imprecise parameter estimates and; (2) errors in the values of the explanatory variables which must themselves be forecast. (See Allen, 1984). It should be remembered that the second source of error may clearly be as great or greater than that due to the first.

FOOTNOTES

1 See for example Bohi and Zimmerman [1984] who provide an update on state-of-the-art energy demand models.

2 The models were estimated with current real average price and with real average price lagged one period. Lagged average price was used because of the potential simultaneity between average price and the quantity of electricity consumed. Both linear and double logarithmic functional forms were used, and were estimated via ordinary least squares techniques. The simultaneity issue is of particular concern because of the existence of declining block rate schedules. If average price is in fact endogenous, and not modeled accordingly, OLS estimating techniques can produce own price elasticity values which are biased upward. Rate schedules have tended to become flatter since the mid 1970's and simultaneity is now less of a concern. However, this could mean that results for the pre embargo period are biased upward as compared to those since the embargo.

3 Not all researchers agree. For example, Bohi and Zimmerman (1984) attempted to determine if price elasticities have changed by comparing elasticity estimates based on post 1974 observations to those from the pre embargo era. They conclude that there is no change, but this is based upon the results of only four studies which employed post embargo observations. Of these, three included data through 1979 and only one included observations for 1980.

Blattenberger; et al (1983) tested for structural change by partitioning 1960-1975 data into periods of rising and falling price and into periods of slow and rapid price change. No significant differences were found, but the data included only a very short period of time since the embargo.

4 The time trend variable serves as a proxy for changes in appliance efficiencies. The price and availability of substitute fuels is included indirectly through the dummy variable.

5 The idea that demand may be asymmetric can be attributed to Marshall [1920] and Duesenberry [1967], followed by Scitovsky [1978]. Duesenberry's theory of the consumption function suggests that the demand for many commodities may be influenced by cyclical price troughs which induce consumption and encourage habit formation. Thus, when prices are rising, past low prices may exert greater influence over behavior than current prices. Scitovsky [1978] also supports this hypothesis, arguing that habits are more easily acquired than broken.

6 Such a policy must be carefully used, however. An increase in efficiency is effectively a decrease in the operating cost of an appliance, which would encourage greater utilization of the appliance. An analysis of the impact of increased efficiency must therefore examine this price effect (see Khazzoom [1980]).

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