Testing for Changes in the Price Elasticity of Residential Electricity Demand

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The demand for electricity in the residential sector is estimated to have become less elastic for the recent period of rising real prices as compared to earlier periods of stable or falling real price. Several possible reasons for this are investigated and we conclude that demand appears to be asymmetric with respect to price in both the short and long run. We then examine whether or not this is an important factor for forecast accuracy and public policy.

Introduction

Reliable price elasticity estimates are becoming increasingly important in planning for future electric generating capacity, for projecting utility capital requirements and for the design of alternative electricity price and regulatory policies.

During the 1950's and 1960's relatively little thought was given to the role of price in demand management or load forecasting. The real price of electricity fell rather consistently and demand forecasts based upon judgment, trend line extrapolation and simple correlation proved to be quite accurate. (See Ascher, 1978.)

The post oil embargo era has been much less stable and most of the demand forecasts prepared between 1970 and 1973 yielded enormous error (see Ascher, 1978 and Figure 1). This stimulated interest in modeling energy demand and attention began to focus on the price elasticity of residential electricity demand. (See Taylor, 1975.)

The sudden increase in energy prices in 1974, following years of stable or declining real prices provided an opportunity to test a number of hypotheses about demand and at least twenty econometric studies of residential electricity demand were published between 1975 and 1984. (See Bohi and Zimrnerman, 1984.) However, only a few studies tested for changes in the structure of demand.

In this paper we report results suggesting that the own price elasticity of the residential demand for electricity in New England has changed since the embargo. Several reasons for this change are discussed. 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 and the design of alternative price policies.

The Evidence

The length of run presents a major problem both for detection and interpretation of changes in the price elasticity of 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.

Several different approaches have been used in econometric analysis to distinguish between lengths of run.[1] The simplest approach involves estimating a static model with quan-

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

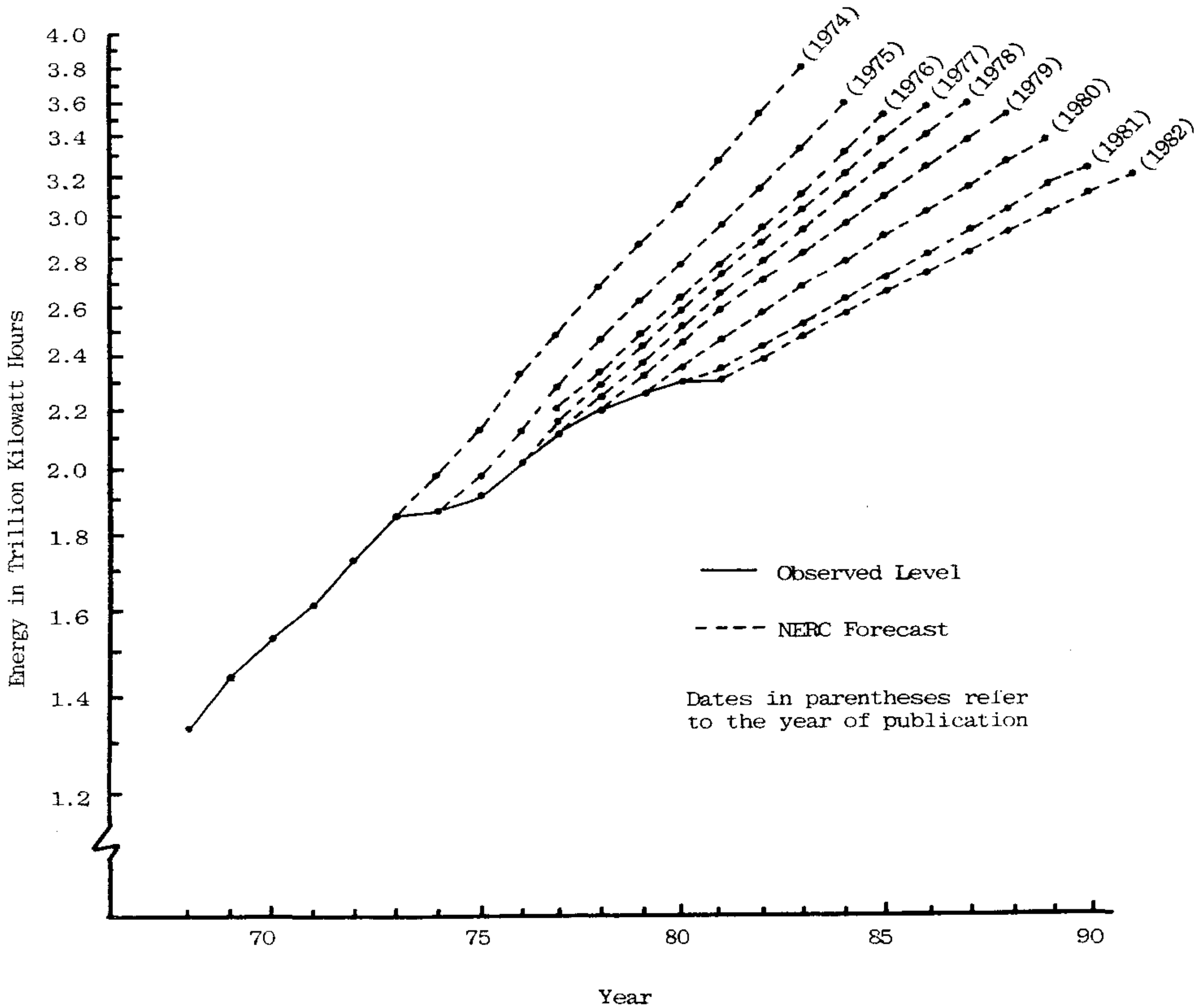

Figure 1. Forecasts of Electric Energy Needs in the United States Published by the National Electric Reliability Councils (1974-82)

tity of electricity consumed regressed against its price, the price of substitute fuels, consumer income, and a vector of other variables such as climate, etc. The distinction between lengths of run is then usually inferred from the type of data used.

Models estimated from cross-sectional data have 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 sumably 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 models which pool time-series and cross-sectional data reinforces the need for careful model interpretation. Whether results are considered to be long or short run depends on conditions in the market under analysis, and it now appears that the type of data used cannot be re-

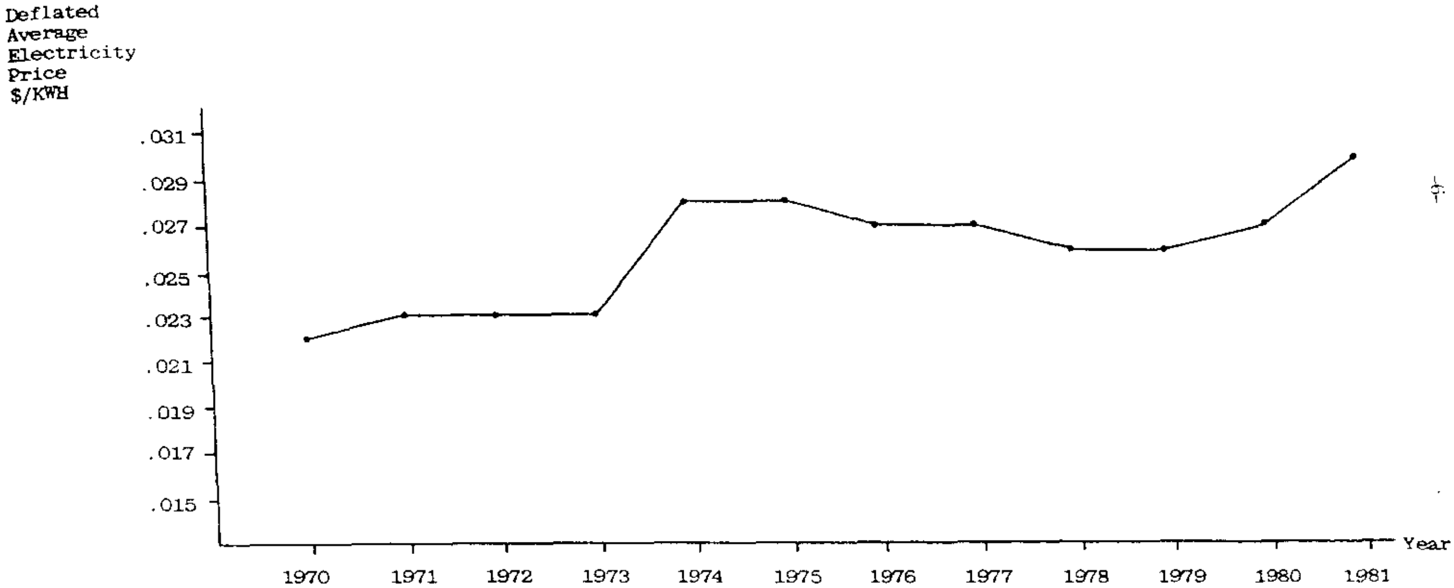

Figure 2. Average Electric Prices, New England (1967 Dollars)

lied upon to define long- 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 (a distributed lag for example), 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 more clearly captures the essence of long-run adjustments, 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:

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

where:

Q_{it} = Quantity of electricity demanded per customer in time t in utility i.
P_{it} = Average real price of electricity in utility i in time t.
Y_{it} = Average yearly real household income in each utility's service area.
T_t = An index designating the year, t = 1, . . . 12.
D_J = Dummy variable for each state.
K_{it} = Sum of the saturation of electrical appliances, weighted by average use, 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 1973-1974 (see Figure 2).

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

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

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.

[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.

Table 1. Summary of Own Price Elasticity Estimates

	Elasticities		
Region	Period	Run	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 significant at the 90% level.

The long-run elasticities were then calculated from (1) and (2) by the procedure suggested by McFadden, et al (1977).

Short-run and long-run own-price elasticity estimates are summarized in Table 1. 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 Learner (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, or level of aggregation?

The range of results from alternative model specifications are presented in Table 2. The alternatives examined included reduced form models with a lagged adjustment mechanism, log and linear functional forms, alternative definitions of the price variable (current and lagged average price), and several different levels of data aggregation.[4] 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 pattern, while several researchers 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 result in *larger* elasticities being observed since the embargo. First, new appliances have become relatively more energy efficient over time, but these changes could not be modeled because of insufficient data.[5] As a result, own price elasticities might be biased upward. At each price, kwh consumed will likely decline as efficiencies increase, so that elasticities might appear to have increased since the embargo. Second, own-price elasticities are expected to increase as electricity becomes a larger proportion of total household expenditures; *ceteris paribus*.

There are, however, many arguments which support our empirical findings of smaller post-embargo elasticities. These arguments are based on 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 constant. First, the theory of habit formation suggests the possibility of asymmetry in short-run demand response. In particular, habits related to the use

[3] Not all researchers agree. For example, Bohi and Zimmerman

those from the pre-embargo era. They conclude that there is no change, but tMs- 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] Data limitations precluded the estimation of structural demand models for electric heat customers or for data aggregated to the state level.

[5] 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.

Table 2. 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	70-75	-.60to -.53	-1.0 to -.98	-.11 to -.09	-2.75 to -1.05
All Customers	76-81	- .41 to - .22	- .48 to - .44	-.29 to -.18	- .82 to - .43
Northern New England	70-75	-.51 to -.46	—	-.53 to -.12	-5.9 to -1.4
All Customers	76-81	- .36 to - .34	—	-.33 to -.29	-.76 to -.64
Southern New England	70-75	- .53 to - .28	-1.18 to -.99	-.08 to +.10	-5.0 to -1.43
All Customers	76-81	-.39	- .73 to - .66	-.33	-.61
New England	67-74			-.94 to -.41	- 1.42 to -.61
Electric Heat Customers	75-81			- .24 to - .23	- .34 to - .33
Northern New England	67-74			- .67 to - .50	- .92 to - .75
Electric Heat Customers	75-81			-.23 to -.22	-.35 to -.31
Southern New England	67-74			-1.6 to -.80	-2.03 to -.99
Electric Heat Customers	75-81			- .44 to - .43	- .60 to - .58
II. State Level					
New England	70-75			- .25 to - .24	
All Customers	76-81			-.10 to -.06	
Northern New England	70-75			-.57 to -.18	
All Customers	76-81			-.13 to -.04	
Southern New England.	70-75			- .40 to - .09	
All Customers	76-81			-.05 to -.15	
III. National Level					
Time Series	47-74			-.93 to -.86	
All Customers	74-77			-.48 to -.38	
Young, Stevens, Willis (1983)					
Pooled cross-section					
Yang (1978)					

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.[6]

Second, ownership of so-called "luxury goods" creates the possibility of price asymmetries in the long run. People probably initially purchased many of their electrical appliances during the pre-embargo years 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 be reluctant to change. As electricity prices rise, alternatively fueled appliances will be substituted when available, feasible, and economical. However, most people would probably be unwilling to sacrifice color television sets, dishwashers, self-cleaning ovens, etc. 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 responding 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 wide-

[6] 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.

spread economic uncertainty and rapidly rising interest rates, coupled with the lack of readily accessible second-hand markets, may have induced 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 has been an increase in the effective degree of asset fixity. This would imply that the post-embargo elasticity will increase over time, gradually approaching the pre-embargo value.

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.[7]

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 of 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 appears to have 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

[7] 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).

of responses which can result from habit in the short run and addiction to a particular lifestyle or investment irreversibility in the long run. Although we were unable to make the latter distinction empirically, our findings raise an important issue for additional study and may contribute to our understanding of consumer behavior.

The importance of our results for forecast accuracy and policy formulation are, however, less clear. The degree of price respon-siveness must be estimated accurately for forecast precision. Knowledge of short run responsiveness is needed for load forecasting, given a level of generating capacity; while long-run price responsiveness guides capacity planning decisions. There are two major sources of errors associated with econometrically based forecasts: (1) biased or imprecise parameter estimates resulting from improper model specification which this paper addresses and (2) errors in the values of the explanatory variables, which must themselves be forecast (see Alien, 1984). It should be remembered that the second source of error may clearly be as great or greater than that due to the first.

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