ENERGY CONSUMPTION AND FUEL CHOICE BY RESIDENTIAL AND COMMERCIAL CONSUMERS IN THE UNITED STATES

by

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INTRODUCTION:

A number of studies have attempted to analyze the determinants of energy consumption by fuel type for natural gas, oil, and electricity[1]. By and large these studies have focused on one fuel source at a time, giving recognition to important substitution possibilities between fuels, if at all, through the inclusion of prices for one or more alternatives. Since most services requiring energy as an input can be provided with several alternative fuels[2], we believe that the possibilities for inter-fuel substitution must be taken into account more explicitly if econometric models are to be useful for evaluating alternative public policies. In this paper we specify and estimate a model of total energy consumption in the residential and commercial sector in the United States, and the distribution of energy consumption among the three energy sources used extensively there: gas, oil, and electricity[3].

Our conceptualization of the fuel choice decision can be summarized in the following way: the consumer decision-making process is composed of two steps. First, the consumer decides on a level of energy using services

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[1] Fisher and Kaysen, Anderson, Halvorsen, Balestra, Houthaker and Taylor are all excellent examples.

[2] See Baughman and Joskow (5)

[3] See "Patterns of Energy Consumption in the United States", Stanford Research Institute, January 1972.

that he desires based on the price of energy, the prices of other goods and services, and household income. This decision defines the expected level of energy that will be consumed. The consumer then seeks to find a combination of fuels that will provide these sources most cheaply. Obviously, this two step procedure is not completely recursive in reality, but has strong simultaneities associated with it. However, as a "first cut" conceptualization, we believe that this is a useful way of looking at things. In any case we have built simple feedback mechanisms into our final model that we use for simulation purposes.

The paper proceeds in the following way: the first section sets up the basic model that is used for estimation. The model consists of two parts; the first is a flow adjustment model that determines total energy consumption in the residential and commercial sectors as determined by an energy price index, an index of consumer prices, and household incomes. The second part of the model consists of a set of "fuel split" equations that determine the distribution of total energy consumption among three energy sources: natural gas, oil, and electricity. A multinomial logit model is used for this purpose. Section two presents estimates of the parameters of this model based on time series-cross section data for 49 states for the period 1968-1972. The third section uses these estimated relationships to make projections of total energy consumption and fuel usage for the residential and commercial sector based on four possible scenarios of the future of individual fuel prices. We find that changing relative energy prices (relative to the prices of other goods and services and relative to each other) have important effects on the level of energy consumption and its distribution among fuels. The final section presents our conclusions.

THE MODEL

The model consists of two parts, the first a relationship for total energy consumption and the second a set of "fuel split" equations. We discuss the energy consumption equation first.

Our basic model for the demand for energy in the residential and commercial sector is a simple flow adjustment model. The desired demand for energy at time t in state i (q_{it}^*) depends upon the price of energy relative to prices of other goods and services (P_{it}) income per capita (Y_{it}) and various demographic variables (Z_{it}).

$$(1) \quad q_{it}^* = f(Y_{it}, Z_{it}, P_{it}, \varepsilon_t)$$

[ε_t is a random disturbance term].

But since energy consumption at a point in time depends on durable good stocks, actual consumption (q_{it}) may not be completely adjusted to desired consumption. As a result we specify the following adjustment relationship.

$$(2) \quad q_{it} - q_{i,t-1} = \gamma\,(q_{it}^* - q_{i,t-1}) \qquad 0 < \gamma < 1$$

If we make desired consumption linear in the independent variables

$$(3) \quad q_{it}^* = \beta_0 + \beta_1 P_{it} + \beta_2 Y_{it} + \beta_3 Z_{it} + \varepsilon_t$$

the final consumption relationship can be written in terms of observable variables.

$$(4) \quad q_{it} = \beta_0\gamma + \beta_1\gamma P_{it} + \beta_2\gamma Y_{it} + \beta_3\gamma Z_{it} + (1-\gamma)q_{i,t-1} + \gamma\varepsilon_t$$

For our fuel split model we make use of the multinomial logit or "log-odds" specification[4]. That is, we explain the relative market shares of the different fuels as a function of the prices of these fuels, household incomes and a set of demographic characteristics. Since in the residential and commercial sector we are concerned with three fuel alternatives, the basic fuel split model becomes the following after allowing for adjustment lags in fuel substitution in the same way as discussed above.

(5a) $$\ell n \left(\frac{S_1}{S_3}\right)_t = \delta_0 + \delta_1 \ell n P_{1_t} + \delta_2 \ell n P_{3_t} + \delta_3 Y_t + \delta_4 Z_t + \delta_5 \ell n\left(\frac{S_1}{S_3}\right)_{t-1} + \varepsilon_{1_t}$$

(5b) $$\ell n \left(\frac{S_2}{S_3}\right)_t = \gamma_0 + \gamma_1 \ell n P_{2_t} + \gamma_2 \ell n P_{3_t} + \gamma_3 Y_t + \gamma_4 Z_t + \gamma_5 \ell n\left(\frac{S_2}{S_3}\right)_{t-1} + \varepsilon_{2_t}$$

(5c) $$(S_1 + S_2 + S_3)_{i,t} = 1$$

where

δ_5 and γ_5 are the "adjustment" parameters (to be estimated)

S_i = market share of fuel i.

P_i = price of fuel i.

Y = household income.

Z = a set of demographic characteristics.

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[4] This specification is based on a theory of individual fuel choice behavior that has been presented elsewhere. See Baughman and Joskow (5) and Joskow and Mishkin (10).

Because there are differences in efficiency of conversion of alternative energy forms into useful heat and power in the household and commercial market, however, the reported data on prices and consumption are really measuring different commodities. An illustration of this is provided by comparing the use of oil and electricity for heating. While electricity may cost \$7.32 per million BTU's (2.5¢/kwhr.), each BTU delivered is effectively converted at an efficiency of 1.0 into 1.0 BTU of heat, but oil, costing \$1.33 per million BTU's (20¢ per gallon) may have an efficiency of conversion to useful heat into the house of only 0.5, i.e. for every BTU delivered only 1/2 BTU ends up as useful heat in the house. Per "effective BTU", therefore, the oil really costs \$2.66 per million BTU's, and only half the number of the reported consumption of BTU's are "effective BTU's".

The coefficients of the price terms in the fuel-split equations (δ_1, δ_2, γ_1, γ_2) can be interpreted as the implicit weight given fuel prices relative to the effects of income, capital costs, and the other demographic variables in the fuel choice decisions. In this specification, other non-price factors are accounted for either explicitly in the other explanatory variables, or implicitly in the values of the constant terms (δ_0 and γ_0)[5], but the weight given to alternative fuel prices may not be the same because of differences in conversion efficiency. To net this, we have transformed all data used for estimating the equations to effective BTU's by correcting for differences in conversion efficiency.[6]

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[5] One of the big factors not explicit is the capital cost of alternative fuel-specific consuming tecnologies. Since there was no good data available for this quantity we had no choice but to include its effect in the constant terms. For a discussion of capital costs see Baughman and Joskow (5).

[6] If λ_i is the conversion efficiency for fuel i, then the consumption of effective BTU's of fuel i (q_i) is related to the reported data ($\hat{q}_i$) by

$$q_i = \lambda_i \hat{q}_i$$

and the effective price for fuel i (P_i) is

$$P_i = \hat{P}_i/\lambda_i$$

We have experimented with a range of efficiencies, but the estimation results were rather insensitive to values between 0.3 and 0.8. The values used to derive the results reported in the next section were 1.0 for electricity and 0.5 for oil and gas.

Once this is done, all price terms measure a common attribute and therefore their coefficients all need to be constrained to be equal in magnitude via the relationship:

$$(5d) \quad -\delta_1 = +\delta_2 = -\gamma_1 = +\gamma_2$$

In addition, to maintain long-run consistency it is necessary that the adjustment parameters (δ_5 and γ_5) also be equal. Otherwise, in the long-run the relative weightings of prices would be different.

The equations we seek to estimate thus become

$$(6) \quad \hat{q}_{i,t} = \beta_0 \gamma + \beta_1 \gamma P_{it} + \beta_2 \gamma Y_{it} + \beta_3 \gamma Z_{it} + (1 - \gamma) \hat{q}_{i,t-1} + \gamma \varepsilon_t$$

and

$$(7a) \quad \ell n \left(\frac{\hat{S}_1}{\hat{S}_3}\right)_{i,t} = \delta_0 + \delta_2 \ n \left(\frac{\hat{P}_1}{\hat{P}_3}\right)_{i,t} + \delta_3 Y_{i,t} + \delta_4 Z_{i,t} + \delta_5 \ \ell n \left(\frac{\hat{S}_1}{\hat{S}_3}\right)_{i,t} + \varepsilon_1$$

$$(7b) \quad n \left(\frac{\hat{S}_2}{\hat{S}_3}\right)_{i,t} = \gamma_0 + \delta_2 \ \ell n \left(\frac{\hat{P}_2}{\hat{P}_3}\right)_{i,t} + \gamma_3 Y_{i,t} + \gamma_4 Z_{i,t} + \delta_5 \ \ell n \left(\frac{\hat{S}_2}{\hat{S}_3}\right)_{i,t} + \varepsilon_{2_t}$$

$$(7c) \quad (\hat{S}_1 + \hat{S}_2 + \hat{S}_3)_{i,t} = 1$$

Equation (6) determines total energy consumption and equations (7a), (7b) and (7c) its distribution among fuels. A "feedback" from the fuel split equations to the total consumption equation is preserved since the fuel split equations determine the weights on the energy price index that appears as an explanatory variable in the total consumption equation.

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[7] See Joskow and Mishkin [10], pp. 4-6, and McFadden [12].

VARIABLE SPECIFICATION, ESTIMATION AND EMPIRICAL RESULTS:

These relationships were estimated using a time series of data for 49 states for the period 1968-1972. The empirical specification of equation (6) is the following[8]:

$$(8)\quad \ell n(q_{i,t}) = \beta_0 + \beta_1 \ell n(P_{i,t}) + \beta_2 Y_{i,t} + \beta_3 N_{i,t}$$

$$+ (1-\gamma)\, \ell n(q_{i,t-1}) + \beta_4 MT_{i,t} + \beta_5 LT_{i,t}$$

where[9]

$q_{i,t}$ = energy consumed per capita in state i in year t.

$Y_{i,t}$ = income per capita.

N_i = population density.

$P_{i,t}$ = energy price index relative to consumer price index.

MT_i = average temperature of warmest three months of the year.

LT_i = average temperature of coldest three months of the year.

A priori, we expect that β_1 will be negative and β_2 positive.

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[8] We have experimented with a number of specifications of equations (1) and (2). The specification which gave us the best statistical results was:

$$(1^1)\quad \ell n\, q_{i,t}^* = \alpha_1 + \beta_1 P_{i,t} + \beta_2 Y_{i,t} + \beta_3 Z_{i,t} + \epsilon_t$$

$$(2^1)\quad q_{i,t} = q_{i,t-1}^{(1-\gamma)} q_{i,t}^*$$

[9] The data are discussed in Appendix A.

The quantity $(1 - \gamma)$ should be positive but less than unity and β_3 should be positive. The temperature variables are a surrogate measure for heating and air conditioning needs. One would expect that minimum temperature would be negatively related with energy consumption. The higher the minimum temperature the less the heating demand ($\beta_4 < 0$). On the other hand, the maximum temperature variable is a surrogate measure of air conditioning needs. Since higher summer temperatures reflect a greater need for air conditioning, one would expect the sign of Maxtemp to be positive ($\beta_5 > 0$).

In the presence of serial correlation, ordinary least squares estimation of (8) will yield inconsistent estimates because of the presence of a lagged dependent variable appearing on the right hand side of the equation. Additional problems may arise because of the use of cross-sectional data where there are differences among states. Perhaps the best way of handling this problem is to use the error components technique of Balestra and Nerlove[10]. An alternative technique for obtaining consistent estimates is to use an instrumental variable estimating technique (to correct for serial correlation) and separate state dummy variables to remove the cross-sectionally related error structure. Due to the short time duration of our sample period (1968-1972) it is difficult to obtain reliable estimates of each state's serial correlation coeffficent, so an instrumental variable technique. was chosen for application here[11]. Also, we utilize the temperature variables as surrogates for cross-sectional dummies, since there is little variation in time of these quantities.

Our estimation results for total energy consumption in the re-

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[10] See Balestra and Nerlove. [3]

[11] The instrumental variable technique consists of estimating the lagged dependent variable as a function of other exogenous variables in the system. The fitted value of the lagged variable is then substituted in the final estimating relationship. The fitted value is uncorrelated with the error term and ordinary least squares performed on the transformed relationship will yield consistent estimates.

sidential and commercial sectors were the following : (t-statistics) are reported in parentheses).

$$(9)\quad \ln(q_{i,t}) = \underset{(1.79)}{1.00} - \underset{(-3.81)}{.134} \cancel{\times 10^{5}} \ln(p_{i,t}) + \underset{(1.65)}{2.69 \times 10^{-5}}\, Y_{i,t} + \underset{(2.27)}{9.36 \times 10^{-6}}\, N_{i,t}$$

$$+ \underset{(26.4)}{0.842} \ln(q_{i,t-1}) - \underset{(-2.02)}{0.00121} LT_{i,t}$$

$$R^2 = .929 \qquad F(5/239) = 621$$

All of the coefficients except that for the maximum temperature variable were significant and of the proper sign[1]. The long-run price elasticity of total demand computed from this equation is -0.80 for the mean state, but this holds only if all fuel prices increase proportionally and no fuel switching takes place. This figure therefore is an upper bound on the price elasticity before consumers are allowed to readjust their consumption bundle in response to the new prices (we discuss this further after developing the fuel split equations more completely). The income elasticity of total energy demand is 0.62 for the mean state. From those results it can also be seen that the value of γ as defined in equation (2) is 0.16. Using this value for γ it is possible to derive a rate of adjustment for total consumption. Recall that our adjustment specification is:

$$q_{i,t} = q_{i,t-1}^{(1-\gamma)}\, q_{i,t}^{*\gamma}$$

where $q_{i,t}^*$ is given by (3) in the previous section. If we assume for

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[12] The coefficient of maximum temperature was $-9. \times 10^{-4}$ with a t-statistic of -1.0, so it was dropped from the equation.

the moment $q_{i,t}^{*}$ remains constant, then the adjustment process operates so that

$$q_{i,t+n} = q_{i,t}^{(1-\gamma)^n} \; q_{i,t}^{*(1-(1-\gamma)^n)} \qquad n = 1,2,3, \ldots$$

and as n goes to infinity $q_{i,t+n}$ approaches $q_{i,t}^{*}$. For $\gamma = 0.16$, after five years consumption is about 60% adjusted and after thirteen years is about 90% adjusted.

The short run (one year) price and income elasticities can be derived by using these adjustment parameters. After one year, the total consumption in the residential and commercial market is approximately 16% adjusted. This implies that the short run price elasticity of demand in this sector is about -0.12, while the short run income elasticity is 0.10.

We now turn to the fuel split relationships. The empirical specification of (7a), (7b), (7c) and (5d) is the following:

$$(8) \quad \ln\left(\frac{\hat{S}_g}{\hat{S}_e}\right)_t = \delta_0 + \delta_2 \ln\left(\frac{\hat{P}_g}{\hat{P}_e}\right)_t + \delta_3 Y_t + \delta_4 MT_t + \delta_5 LT_t + \delta_6 \ln\left(\frac{\hat{S}_g}{\hat{S}_e}\right)_{t-1}$$

$$(9) \quad \ln\left(\frac{\hat{S}_o}{\hat{S}_e}\right)_t = \gamma_0 + \delta_2 \ln\left(\frac{\hat{P}_o}{\hat{P}_e}\right)_t + \gamma_3 Y_t + \gamma_4 MT_6 + \gamma_5 LT_t + \delta_6 \ln\left(\frac{\hat{S}_o}{\hat{S}_e}\right)_{t-1}$$

$$\hat{S}_o + \hat{S}_3 + \hat{S}_g = 1$$

where[13]:

$\hat{P}_g$ = effective price of gas (1972 dollars)

$\hat{P}_e$ = effective price of electricity (1972 dollars)

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[13] The data are discussed in Appendix A.

$\hat{P}_o$ = effective price of oil (1972 dollars)

Y = per capita income.

LT = average temperature for coldest three months.

MT = average temperature for warmest three months.

$\hat{S}_o$ = proportion effective total BTU consumption oil.

$\hat{S}_g$ = proportion effective total BTU consumption gas.

$\hat{S}_e$ = proportion effective total BTU consumption electricity.

Again, one must correct for the simultaneous cross-sectional and time-series nature of the estimating relationships. We have utilized the same instrumental variable estimating technique with temperature variables used as a surrogate for state dummies as described above. A test of the residuals after initial estimates when this procedure was followed, however, revealed the persistance of heterostedastic disturbances. Errors were positively correlated with the amount of oil consumption in the state.

If one assumes that the consumption of any fuel in a state reflects the number of individual decisions made in favor of that fuel, then the variance of the observed mean frequency (market share in this context) is proportional to the reciprocal of the number of decisions(N). To assure that the residual error terms of the estimated equations have constant variance, each observation has to be multiplied by the square root of N (in our case the square root of consumption). This weighting procedure yielded much better estimated relationships and was used throughout in the estimation of the fuel split equations[14].

The estimation results based on a time series of cross sections for 49 states over the period 1968-1972 were the following: (t-statistics are in parentheses).

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[14] See Theil (1972), pp. 174-177 and Theil (1971), pp. 631-633.

$$\ln\left[\frac{\hat{S}_g}{\hat{S}_e}\right]_t = \underset{(-0.86)}{-\,0.196} \; \underset{(-3.06)}{-\,0.128} \ln\left[\frac{\hat{P}_g}{\hat{P}_e}\right]_t \; \underset{(-0.53)}{-\,8.02 \times 10^{-4}}\, MT_t \; \underset{(-1.83)}{-\,0.00234}\, LT_t$$

$$\underset{(1.44)}{+\,6.36 \times 10^{-5}}\, Y_{c_t} \; \underset{(65.9)}{+\,0.895} \ln\left[\frac{\hat{S}_g}{\hat{S}_e}\right]_{t-1}$$

$$\ln\left[\frac{\hat{S}_o}{\hat{S}_e}\right]_t = \underset{(-0.51)}{-\,0.121} \; \underset{(-3.06)}{-\,0.128} \ln\left[\frac{\hat{P}_o}{\hat{P}_e}\right]_t \; \underset{(-1.26)}{-\,0.00175}\, MT_t \; \underset{(-3.37)}{-\,0.0066}\, LT_t$$

$$\underset{(1.68)}{+\,9.02 \times 10^{-5}}\, Y_{c_t} \; \underset{(65.9)}{+\,0.895} \ln\left[\frac{\hat{S}_o}{\hat{S}_e}\right]_{t-1}$$

$$R^2 = .95 \qquad F = 1144$$

It can be seen that coefficients of the price terms are quite significant and exhibit the proper sign. The temperature variables indicate that the higher the average temperatures the more electricity is favored over gas and oil, with the effect more significant for the minimum temperature terms (LT). The income terms reveal the startling result that higher income areas prefer fossil fuels relative to electricity, all else being equal. However, like the maximum temperature terms, neither income coefficient is significant at the 1% level of significance. There does exist some collinearity between incomes and maximum temperatures, so we also estimated the equations with the income terms absent to see if we might be picking up an air-conditioning effect. The net result, however, was to increase in the negative direction the values of the maximum temperature terms and slightly increase their significance, but everything else stayed essentially the same. Given the lack of significance of the income coefficients, one has to conclude that incomes apparently are not a predominant factor in aggregate fuel choice decisions. Incomes do influence the total level of consumption; this result was confirmed in the total demand equation. However, after correcting for average user efficiencies, fuel prices and utilization patterns are determined by the temperature variables, are more important determinants of fuel choice.

The coefficient of the lagged dependent variable has a value of 0.895. This corresponds to a 90% adjustment time of about 20 years in the mix of fuels consumed. Since there were no great movements over the period of our sample, however, it is likely that this value may be biased upward. In time of rapid price changes like has been experienced over the last two years it is likely that consumers would adjust more quickly. In the simulations discussed in the next section, we constrain the adjustment parameter in the fuel-split equations, i.e., the coefficient of the lagged dependent variable, to be equal to that of the total demand equation, which implies a slightly faster adjustment time than was estimated here.

The matrix of "market share" elasticities and cross-elasticities can be computed from the estimated relationships.[15] These are shown in Table 1. Table 1a shows the symbolic elasticities; Table 1b shows the same matrix for our estimated coefficients and mean values of the price and market share variables. The behavior of the elasticities and cross-elasticities is most enlightening. The relationships indicate that as any given market share increases, the own-price elasticity decreases and the cross-elasticities increase. This is not unreasonable, for as the market share increases, we approach the saturation point and the own-price elasticity should decrease. At this same high market share, a shift of consumption to another fuel with a low market share is a large percentage increase, consequently the high cross-elasticities. At the other extreme, as the market share approaches zero, the cross-elasticities go to zero. In this case, the impact of any shift on the market share of competing fuels is minimal.

By putting the total energy demand equation together with the fuel split equations, we can obtain the more familiar total price and cross-price elasticities. These are reported in Table 2 for mean values of the relevant variables for the long run (complete adjustment). These were derived from simulation runs around a trajectory of prices. Each fuel's price was individually perturbed by 5% over the period of the simulation from a set of base prices and from the resulting changes in demand the relevant elasticities were computed. This is the same procedure used by the F.E.A. in the Project Independence Report. See [16]. pp. 58-63 (Appencix AII).

The results in Table 2 reveal that the long-run own-price elasticities are all in the neighborhood of -1.0 to -1.1, with oil displaying the highest value. The maximum long-run cross-elasticities exist in response to gas price changes, taking on values of +0.17 and +0.19, respectively, for electricity and oil. For changes in oil

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[15] These market shares elasticities are not to be confused with total fuel price elasticities. Because price response exists both in market shares <u>and</u> the total level of consumption, both must be accounted for to derive a fuel demand elasticity.

TABLE I

ELASTICITIES OF MARKET SHARES WITH RESPECT TO PRICE

	P_e	P_o	P_g
S_e	$\frac{\delta_2}{1-\delta_6}(1-S_e)$	$\frac{-\delta_2}{1-\delta_6} S_o$	$\frac{-\delta_2}{1-\delta_6} S_g$
S_o	$\frac{-\delta_2}{1-\delta_6} S_e$	$\frac{\delta_2}{1-\delta_6}(1-S_o)$	$\frac{-\delta_2}{1-\delta_6} S_g$
S_g	$\frac{-\delta_2}{1-\delta_6} S_e$	$\frac{-\delta_2}{1-\delta_6} S_o$	$\frac{\delta_2}{1-\delta_6}(1-S_g)$

(a)

COMPUTED USING MEAN VALUES OF PRICES AND NATIONAL MARKET SHARES (1972)

	P_e	P_o	P_g
S_e	-.800	.284	.514
S_o	.414	-.929	.514
S_g	.414	.284	-.698

(b)

prices, the relevant cross-elasticities are + 0.05 and + 0.06, both quite small. The implication is that the most significant response in this sector to changes in the price of oil is not the switching to alternative fuel forms that one finds for gas and electricity, but rather an adjustment in the total level of consumption. This probably results because in the regions where oil is consumed (the Northeast, and the Great Lakes States), the costs of the alternatives are quite high. Increasing the price of oil does not result in switching because of the high cost of the alternatives, but rather an adjustment in the level of consumption.

Other studies have also attempted to estimate the price responsiveness of various fuel demands in the residential-commercial sector. In Table 3 we compare our estimates of the long-run own-price elasticities with results from other studies. For electricity, the estimates of price elasticity range from -0.44 to a -1.5. The F.E.A. has the lowest value (-.44) followed by the Anderson (1972) estimate (-0.9). All the other studies have electricity demand elasticities of -1.0 or larger.

For natural gas, the price elasticities fall into three ranges: Anderson's values which are both greater than -2.0, our value of -1.0 and the other values of -0.4 and -0.6. Again, the F.E.A. has the lowest of the range. For oil, the results cluster much more closely than for either gas or electricity. However, our estimate is not directly comparable to the others as our model includes both distillate and residual oil consumption for the residential-commercial sector. Kennedy and the F.E.A. have estimated values for each product individually.

TABLE 2

PRICE ELASTICITY MATRIX

		p_g	p_o	p_e
GAS	SR	-.15	.011	.006
	LR	-1.009	.055	.168
OIL	SR	.040	-1.79	.007
	LR	.185	-1.121	.156
ELECTRICITY	SR	.045	.011	-.187
	LR	.170	.046	-1.003

SR = Short run (one year) elasticity
LR = Long run elasticity

TABLE 3

COMPARISON OF LONG-RUN OWN-PRICE ELASTICITIES

ELECTRICITY		
Baughman-Joskow	R-C	-1.00
Wilson [18]	R	-1.3
Anderson [1]	R	-0.9
Anderson [17]	R	-1.2
Halvorsen [8]	R	-1.1
Chapman, Tyrrell &	R	-1.3
Mount [20]	C	-1.5
F.E.A. [16]	R-C	-0.44
NATURAL GAS		
Baughman-Joskow	R-C	-1.00
Balestra & Nerlove [2]	R-(	-0.6
Anderson [1]	R	-2.3
Anderson [17]	R	-2.7
F.E.A. [16]	R-C	-0.37
OIL		
Baughman-Joskow	R-C	-1.12
Kennedy [19] distillate**		-0.76
F.E.A. [16] distillate**		-0.64
Kennedy [19] residual**		-1.58
F.E.A. [16] residual**		-0.34

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* R denotes estimate for residential use only, R-C denotes combined residential-commercial use.

** Distillate fuel comprises about 60% of total Residential-Commercial consumption.

ENERGY CONSUMPTION IN THE RESIDENTIAL AND COMMERCIAL SECTOR UNDER DIFFERENT FUTURE PRICE PATTERNS

PROJECTIONS TO 1985

The value of an empirical energy demand system like the one developed in the previous section lies in its ability to give a complete picture of the effects of energy price changes on total energy consumption as well as consumption of individual fuels. The model can be used to assess the effects of changing energy prices arising either from changes in market conditions or as a result of specific public policies such as the imposition of taxes on one or more fuels.

To exhibit the sensitivity of energy consumption in the residential and commercial sector to changing energy prices we use the estimated structural equations of our model to investigate the effects of different possible future fuel price patterns on energy consumption for the years 1977, 1980, and 1985. For these simulations it was assumed that population grows at 1.02% per year and real incomes grow at 3.7% per year over the 1972 base year in each state. Then, using mean values for the temperature variables, a set of simulations with the following price scenarios were performed:

CASE I: Prices for oil, natural gas, and electricity exhibit the same trends as those used in the Federal Energy Administration Project Independence Blueprint for the $7 business-as-usual case.[16]

CASE II: Same as above expect prices are for the $11 business-as-usual case.[16]

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[16] See Appendix AII, figure 9, pg. 69 of the Project Independence Report [16].

CASE III: Some as case II except that from 1976 on a $2 per barrel tax is added to the price of oil.

CASE IV: All prices remain at their 1972 values in real terms.

The results of the simulations are then compared to those presented in the Project Independence Report, Appendix AII, which were derived from the F.E.A.'s unconstrained demand model.

Before discussing the simulation results, it needs to be pointed out that our data base is not directly comparable to the F.E.A.'s. The F.E.A. utilizes Bureau of Mines energy accounts for partitioning their consumption categories, whereas we have derived our numbers from various raw sources (see the Appendix), depending on the fuel. The magnitude of the differences can be seen by comparing actual 1972 consumption numbers from the two data sets.

ACTUAL 1972 CONSUMPTION
RESIDENTIAL AND COMMERCIAL SECTOR
(Trillions of BTU's)

	TOTAL	GAS	OIL	ELECTRICITY
F.E.A.	17787	7642	6667	3478
OUR DATA	14646	7415	4262	2968

The major differences exist in the oil and electricity categories. For oil, the F.E.A. has included in this sector 1137 trillion BTU's of "Asphalt and Road Oils", plus another 1163 trillion BTU's of "Liquefied Gases" and "Kerosine", which are not in our data base. These differences, plus a slight difference in conversion factors of barrels to BTU's explains this discrepancy. For electricity, the F.E.A. has included the categories of "Street and Highway Lighting", "Other Public Authorities", and "Interdepartmental Transfers" in their electricity consumption (comprising 207 trillion BTU's), plus an allocation of transmission and distribution losses, which makes up the difference here. For gas, the difference in conversion factors from cubic feet to BTU's explains the slight discrepancy.

In Table 4, to make the results of the simulations comparable between the two studies, we have scaled the F.E.A. projections for each fuel proportional to the differences existent in the data sets in 1972. The actual F.E.A. reported results are given in parentheses.

Let us first examine the results for each of the four cases using the model estimates presented here. The major differences between the cases is essentially in the price of oil and electricity. In case IV, where all fuel prices remain at their real 1992 values, total energy consumption in this sector rises from a level of 15.5 x 10^{15}BTU in 1973 to 21.2 x 10^{15} BTU in 1985, a compound growth rate of 2.6 percent per year. When we compare Case IV with Case I, where oil prices rise above their real 1972 values to $7 per barrel but real electricity price is unchanged, we find that most of the effect is a reduction in oil consumption with some increase in natural gas consumption. By 1985, oil consumption is 1.7 quads less in Case I than in Case IV, while natural gas consumption increases by 0.3 quads. Since electricity consumption has not changed relative to Case IV, total energy consumption is reduced by 1.5 quads.

In Case II, oil prices rise further to $11 per barrel by 1985. In addition, electricity prices rise above those in Cases I and IV. The effect is a further reduction in oil consumption, a further increase in natural gas consumption and a fairly substantial reduction in electricity consumption. In Case II, oil consumption is 2.6 quads below the Case IV consumption by 1985, a reduction of nearly 50%. Electricity consumption is 0.7 quads lower, a reduction of 15%, and natural gas consumption is 0.6 quads higher.

TABLE 4

SIMULATION RESULTS

(Quadrillions of BTU's)

	TOTAL	GAS	OIL	ELECTRICITY
1977				
F.E.A. I ($7)	16.6 (19.7)	8.7 (8.9)	4.0 (6.2)	3.9 (4.6)
CASE I ($7)	16.3	8.5	3.8	3.9
F.E.A. II $11)	16.2 (19.1)	8.6 (8.8)	3.7 (5.8)	3.8 (4.5)
CASE II ($11)	15.9	8.6	3.5	3.7
CASE III ($2 tax)	15.7	8.6	3.4	3.7
CASE IV	16.8	8.4	4.5	3.9
1980				
F.E.A. I	18.8 (22.2)	9.6 (9.9)	4.1 (6.4)	5.1 (5.9)
CASE I	17.4	9.3	3.7	4.4
F.E.A. II	18.2 (21.3)	9.6 (9.9)	3.6 (5.6)	5.0 (5.8)
CASE II	16.6	9.4	3.2	4.0
CASE III	16.4	9.5	3.0	4.0
CASE IV	18.3	9.1	4.9	4.3
1985				
F.E.A. I	22.7 (26.7)	10.7 (11.0)	4.5 (7.0)	7.5 (8.7)
CASE I	19.7	10.7	4.0	5.1
F.E.A. II	21.8 (25.4)	10.8 (11.1)	3.7 (5.8)	7.3 (8.5)
CASE II	18.5	11.0	3.1	4.4
CASE III	18.3	11.1	2.9	4.4
CASE IV	21.2	10.4	5.7	5.1

In Case III we have attempted to simulate the effects of President Ford's proposed $2 tax on oil imports, which, presuming that imports are greater than zero, will lead to a $2 increase in domestic oil prices if the planned oil price decontrol scheme goes into effect along with it. By comparing Case II to Case III we can see that the $2 tax has a fairly small effect on oil consumption in the residential-commercial sector if oil prices are already as high as $11. The effect in the short run (1977) is only a reduction of 0.1 quad per year and by 1985 the effect is only a reduction of 0.2 quads per year of oil consumption. At least for the residential and commercial sector, the effects of the oil tax would appear to be minimal. However, since only a small proportion of total oil consumption in the U.S. is attributable to this sector, the overall effects of the policy cannot be evaluated. It does seem clear that the effects of the tax on this sector will be largely income effects, rather than substitution effects.

The major difference between the FEA results and those presented here is that price responsiveness is less in the FEA model. Comparing FEA I with FEA II, we see that oil consumption declines by 0.8 quads, a reduction of 18%, by 1985. In the model presented here, the reduction is about 23%. A more striking difference arises in the case of electricity. The difference between electricity consumption in FEA I and FEA II is only a reduction of 0.2 quads out of 7.5, a negligible amount. The equivalent effect associated with our simulations is a reduction in electricity consumption of nearly 15%.

Since natural gas prices do not change in these simulations, it is impossible to compare the responsiveness of natural gas consumption to charging prices. This is obviously important for evaluating the effects of natural gas price deregulation. However, a glance at Table 3 indicates that the residential-commercial gas price elasticity presented here is nearly three times larger than FEA's. This indicates that the effects of natural gas price deregulation on natural gas consumption will be larger than indicated by the FEA model.

Overall, the price elasticity estimates presented here are generally larger than those used by the FEA in the Project Independence Report. The important implications of these results is that energy self-sufficiency may be more easily achieved through price mechanisms alone, including taxes, than one might be led to believe by the FEA results.

CONCLUSION

The purpose of this paper has been to report the conceptual design and estimation results of models for total demand and aggregate fuel choice decisions in the residential and commercial sector. We started with the view that fuel utilization decisions can be separated into a two-level decision process. First, the consumer decides on the level of energy using services he desires to meet his functional needs, then he seeks to find the combination of fuels that will provide these services most cheaply. This dichotomy formed the basis for the models actually adopted.

The model used to explain total demand for energy in the residential and commercial sector is a simple flow adjustment model. The long run price and income elasticities of demand in this sector were estimated to be about - 0.50 (after adjustments of fuel mix) and 0.6 respectively. The short run (one-year) elasticities were about 16% of these values.

A set of simulations were performed using alternative scenarios about the evolution of future prices. The results show that much conservation can be expected to take place in the residential and commercial sector as a result of past and expected future price increases. When comparing our model behavior with that used by the F.E.A. in its Project Independence analyses, the differences indicate that the F.E.A. has overestimated future energy consumption trends for the residential and commercial sector. Also, in response to President Ford's proposed taxes on oil, our model exhibits little additional shift away from that fuel in addition to that expected purely in response to the existing increase of oil prices to $11 per barrel.

APPENDIX A

DATA SOURCES AND DERIVATION:

The data series used for this sector run generally from 1965-1972 by state, i.e. 48 states and D.C., though occasionally, observations on states are by necessity combined. Specifically, there is no gas consumption in Maine and Vermont until 1966, and even then their consumption and price data is combined with that of New Hampshire. In addition, both gas and electricity data for Maryland and the District of Columbia are always combined. Thus, because of the structure of the estimating equations, the total energy demand equation and the gas half of the fuel choice equation observations for Maine, Vermont, and New Hampshire are combined, as are observations for Maryland and the District of Columbia; in the oil half of the fuel choice equation only observations for Maryland and District of Columbia are combined.

The price data (which is at the retail level) is in \$/BTU; the consumption data is in BTU's; income per capita is in \$/person, and all other variables are in similar singular units.

All variables involving dollar figures have been adjusted by the cross-sectional time-series deflator later described.

NATURAL GAS:

Natural Gas Price and consumption data is clearly the most reliable, structurally, of our observations in the residential-commercial sector. The Bureau of Mines (Minerals Yearbook) provides information on sales and revenues by year by state for both the residential and commercial sectors. The sales data, in MCF's, is converted to BTU's by the state conversion factors for electric utilities'fuels consumption found in the Edison Electric Institute's Statistical Yearbook. The prices result from dividing revenues by sales, and the price for the residential and commercial sector is an average of the prices weighted by each sector's consumption.

ELECTRICITY:

Electricity price and consumption data is readily derived from the Edison Electric Institute's "Statistical Yearbook's" Sales and Revenues sections. The data is available for the residential sector specifically, but not for the commercial sector. We have had to assume that the samll light and power figures are roughly proportional to what would be actual commercial sector figures, since no data source separates "commercial" from industrial, but rather, only "small light and power" from "large light and power". The consumption data is converted to BTU's by 3412.8 BTU's/kwh, and the price data, like that of gas, is an average of the residential and small light and power prices weighted by each of these sector's consumption.

OIL:

Oil data is by far the most unreliable of the three energy data sets. If one looks at 13 years of distillate and residual heating oil consumption for particular states, the series suspiciously cycles. This consumption data is found in the Bureau of Mines' Mineral Industry Surveys, "Shipments of Fuel Oil and Kerosine (kerosine used for heating is not included in our analysis), broken down by distillate grades one through four and residual grades five and six. A representative of this publication claims that heating oil used industrially is not consistently included or excluded from the heating oil figures from year to year; so, it is not even possible to explain this noise with a level-of-economic activity regressor.

None of this data is broken down by sector, i.e. residential or commercial or industrial heating use - it is assumed that numbers 1 through 6 distillate and residual heating oil at least exhaust residential and commercial uses of oil substitutable with natural gas and electricity, and is roughly proportional to what would be the actual consumption in these sectors. The raw data, in barrels, is converted by 5.825×10^6 BTU's per barrel of distillate and by 6.287×10^6 BTU's per barrel of residual.

The only retail oil price found on the state level is for # 2 fuel oil. This data was obtained from the American Gas Association. We are well aware of this regressor's unreliability as a distillate-residual oil price in the residential-commercial sector (though it is probably a reasonable surrogate for a distillate oil price in these sectors), but there is nothing more available.

MISCELLANEOUS

The temperature variables used here are the average temperature of the three warmest months and the average temperature of the three coldest months in degrees Farhrenheit. This information is from the Department of Commerce's National Oceanic and Atmospheric Administration publications.

The adjustor used for all dollar figure variables is a time-series, cross-sectional deflator constructed through the work of Kent Anderson for 1970. This 48 state deflator (Maryland and District of Columbia combined) is adapted to 1960 through 1972 by the nation wide consumer price index. This, of course, very strongly assumes that the inflation rates are uniform all over the United States, i.e. that the relative cost of living in each state does not change over time. It is thought that this procedure is no worse than obtaining the cost-of-living studies done by the Bureau of Labor Statistics for three of the thirteen years in question and extrapolating and interpolating the other ten years, especially since this cost of living index is not available by state. Since our research employs cross-sectional time series data and since there is not enough variation in price or any explanatory variable over time to fit a demand curve, it was assumed that a deflator oriented primarily to cross-sectional variation would suffice.

The Anderson index for 1970 is constructed as follows:

> "The 1970 B.L.S. data for SMSA's on the relative living cost of a family of four having an "intermediate" budget permitted construction of an index for state metropolitan areas. Indices for state non-metropolitan areas were set at 90/103 of the metropolitan indices, based upon the U.S. averages for these two types of areas[13]".

Every effort has been made to obtain the best data available -- any suggestions as to better sources of data series would be greatly appreciated.

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