ENERGY LABORATORY

MASSACHUSETTS INSTITUTE
OF TECHNOLOGY

INTERFUEL SUBSTITUTION IN THE CONSUMPTION OF ENERGY IN THE UNITED STATES
PART II: INDUSTRIAL SECTOR

BY

MARTIN L. BAUGHMAN AND FREDERICK S. ZERHOOT

APRIL 25, 1975

ENERGY LAB. REPORT
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INTERFUEL SUBSTITUTION IN THE CONSUMPTION OF ENERGY IN THE UNITED STATES

Part II: Industrial Sector

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Martin L. Baughman and Frederick S. Zerhoot

I. INTRODUCTION

In this paper we specify and estimate a set of derived demand functions for energy in the industrial sector of the United States. United States industrial firms have historically consumed about one third of the nation's total gross energy. Of this total, about 75% goes into generation of process steam or is used as direct heat, about 10% is used in a form of electric drive or for electrolytic processing, another 10% is utilized as feed-stock for production of chemicals, asphalts, lubes, greases, and so forth. The rest is used in other miscellaneous processes. In 1972 the market shares of alternative energy forms consumed in the industrial sector were 45% natural gas, 25% oil, 18.5% coal, and 11.5% electricity, whereas in 1955 the market shares were 33% for natural gas, 22% oil, 38% coal, and 7% electricity.

It is well known that the industrial sector is made up of many diverse manufacturing processes and, correspondingly, each form of manufacture has quite different energy requirements. A convenient dis-aggregation of the industrial sectors' activities is the Census of Manufacturers two-digit Standard Industrial Classification. Figure 1 displays the total consumption for each of the industries in the two-digit SIC classification in 1962. The six largest energy consumers (SIC N°s. 33, 28, 29, 32, 26, 20) account for almost two thirds of the industrial sectors' energy consumption. In Figure 2, using Census of Manufacturers value-added data, we have computed energy intensiveness coefficients for each of the two-digit classifications. The numbers computed are the ratio of expenditures for energy to the total value-added in each sector. Figure 2 shows that, in 1962, energy made up almost 9% of value-added in the most intensive industries (N°. 29 - Petroleum Refining and Coal Products, and N°. 33 - Primary Metals), but only about 1% for the least intensive categories.

Historically, the prices of alternative forms of energy have varied significantly both from state to state as well among fuels within a state; for example, in 1972, the average prices of gas, oil, coal, and electricity consumed in the industrial sector were 52.3¢, 75.1¢, 46.8¢ and $3.67 per million BTU's, respectively. The cross-sectional variation in price was from 23¢ to $1.15 per million BTU's for gas; 46¢ to $1.25 per million BTU's for oil; 20¢ to 68¢ per million BTU's for coal; and 94¢ to $8.34 per million BTU's for electricity.

Based upon the above, our a priori beliefs regarding the model development were: (1) that behavior regarding fuel choice and demand in the sixties was substantially different from that just after the war and that of the fifties; (2) that there was not enough variation in prices of fuels within individual states over time to identify sensible demand functions for each state, but that the cross-sectional variation, after netting out non-price effects, would be sufficient to trace out a set of equilibrium demand functions for each fuel; and (3) that like industry within individual states responded similarly to differences in alternative energy prices so that demand curves applicable to all states could be derived from variation across states. These assumptions motivated our use of pooled cross-sectional time-series data. Similar to previous work in the resi-

FIGURE 1 : DISTRIBUTION OF INDUSTRIAL ENERGY CONSUMPTION, BY STANDARD INDUSTRIAL CLASSIFICATION

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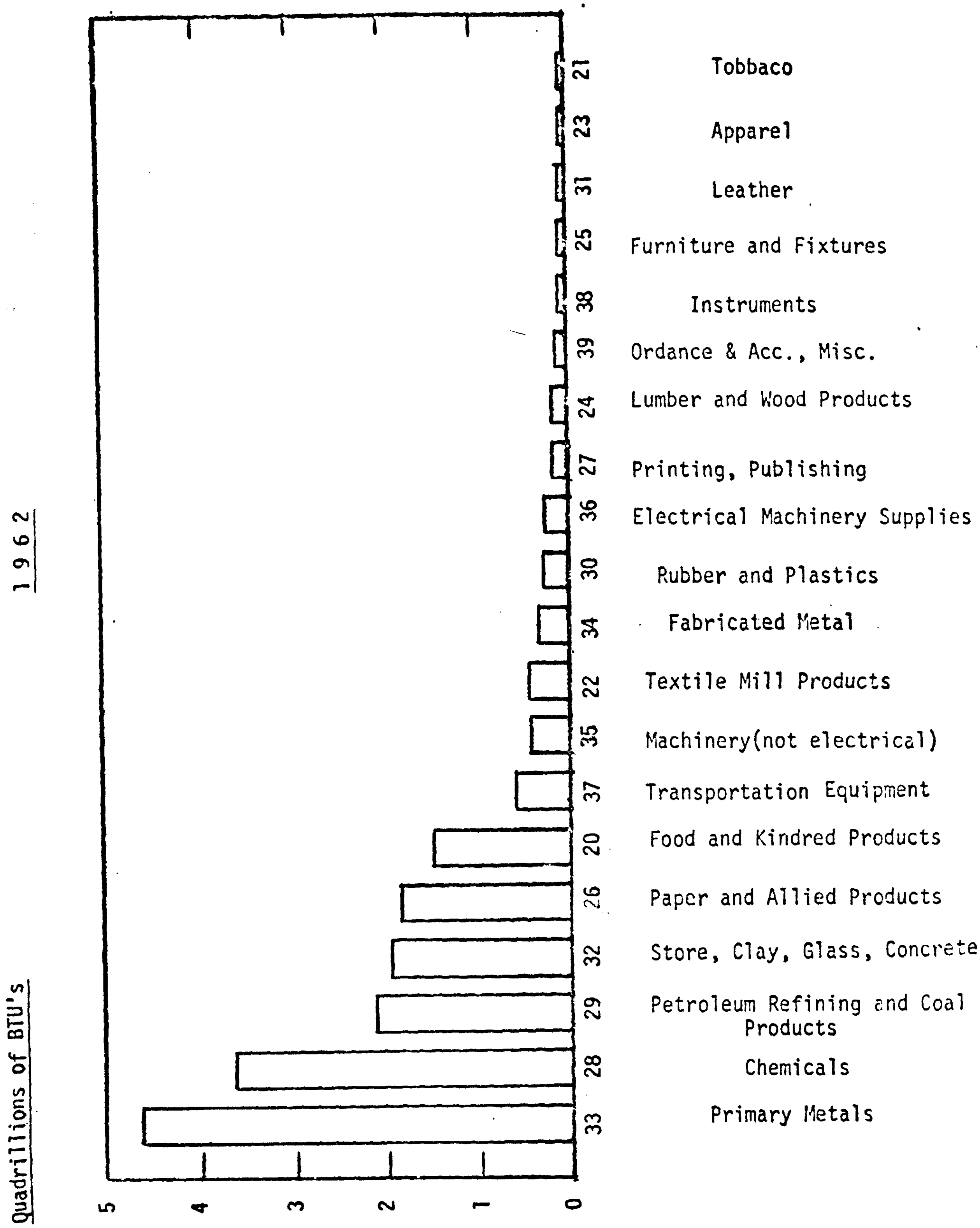
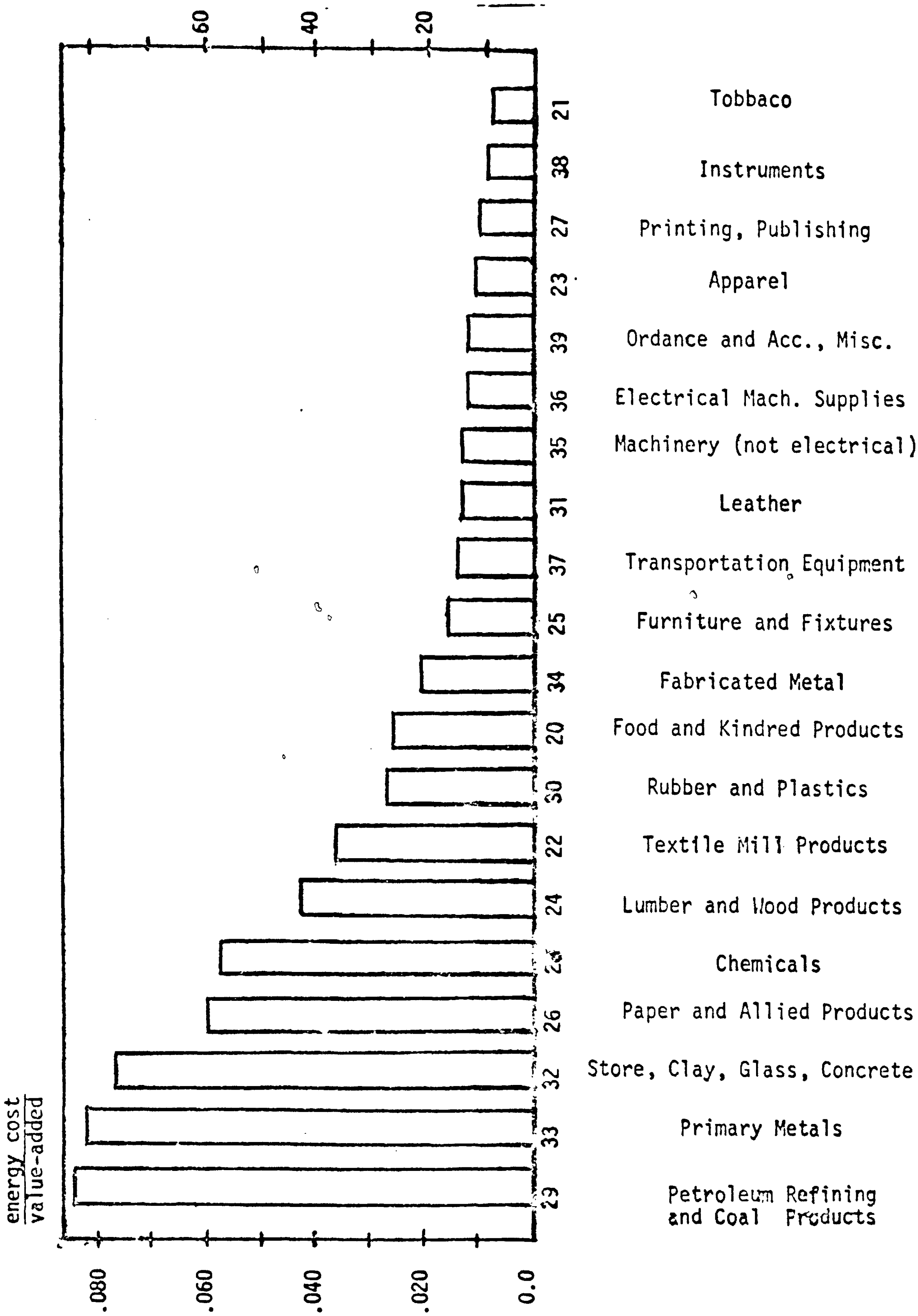


FIGURE 2: 20 TWO-DIGIT S.I.C. CODES BY ENERGY INTENSIVENESS - 1962



dential-commercial sector[1], we have based many of our equation forms upon the conditional logit model.

Although we assume like industry to behave similarly across states, it is likely that different types of industry exhibit different price responsiveness because of differences in their technologies. We have attempted to partially incorporate the variations in behavior that arise from differences in the industrial mix by using interactive variables in our formulation corresponding to fractions of total value-added in each state accounted for by various industry groupings. Some equation forms are reported in footnotes that are specified in this interactive variable formulation. Unfortunately, most likely due to data aggregation problems, we were not able to consistently estimate preferences for fuels among the groupings used. Ideally, we should have liked to have used data by year, by state, by industry group, i.e., fuel prices and consumption and level of economic activity (e.g. value-added) data at the two-digit SIC level. However, no set of data exhaustive of industry groupings exist by state for even one year from any source, including the U.S. Census of Manufacturers publications[2].

One problem, however, that exists in the industrial sector but does not in the residential-commercial sector, is that energy prices may be an important factor in industry's locational decisions. These locational decisions have been incorporated into a three-level decision model presented here. A further problem was the concern that shortages of natural gas, especially in the time period from 1969-1972, would bias the estimates of price responsiveness in the various equations[3]. To circumvent this problem, and at the same time

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[1] See Refs. [1], [2].

[2] See Ref. [3]. Erickson & Spann estimate demand equations for selected two-digit SIC codes for one year of cross-sections, selected because the data is not available for all of them.

[3] Ref. [4] gives a more complete description of the shortages that existed over this time period.

to measure its effect, all equations are estimated and reported over two time periods; from 1962-1967, a period predating the gas shortages and from 1968-1972, the period in which supply interruptions took place. Interestingly enough, we found that the main difference between the two time periods estimates was not in the magnitude of the long run response, but in the short run response to changing prices -- or alternatively, the time required for long run adjustment. Due to the wide cross-sectional variations in fuel prices compared to the relatively small impact that gas shortages had on total consumption patterns, even including the period up to 1972, it is not difficult to see why the long-run cross-sectional effects are nearly equal over the two time periods. For reasons to be explained later, we have used the equations estimated over the second half of the time period for the simulations reported in section III.

In the construction of the data base for the equations estimated and reported, our intention has been to account for as much of the energy consumption by industry as possible. We chose to use energy data disaggregated by state, which is the most disaggregated form we could find that would exhaust the consumption of the U.S. This data included fuel consumption for process heat and motive power uses but neglects petrochemical uses. Petrochemical uses, for the most part, are dependent upon specific energy or chemical forms and therefore are not readily substitutable. So as not to bias the estimates of price responsiveness for the other more substitutable end-use categories, we have intentionally excluded energy used as feed-stocks from our data base. A detailed description of the data and sources used for these analyses is given in the Appendix. With one exception, the data base is similar to that used by the Federal Energy Administration in the development of the industrial demand functions in the Project Independence analyses and reported in the Project Independence Blueprint [5]. The exception is that we have excluded feedstocks.

In the following sections we report the model that has been developed and utilized for these analyses. The discussion proceeds in the following way. First the overall specification of the model is presented in Section II. Next, the applied estimation techniques and estimated results are discussed for each of the three parts of the model. Finally, in section III, sample simulations are reported and compared to recent Federal Energy Administration forecasts.

II. THE MODEL

Discussions regarding energy consumption for individual industrial decision makers can be separated into an interrelated three step process. First, in the production of output in the various industrial sectors there exists the potential for substitution between energy and non-energy factor inputs (capital, labor, materials, etc.). Given a price of energy, one would expect individual decision makers to choose a mix of energy and non-energy inputs that would minimize the cost of production. The energy requirements would, consequently, depend on the cost of energy relative to the costs of other factor inputs and the total output of goods and services .

A second but related level of decision making is the choice of location geographically within the United States. This locational decision is affected by the cost and availability of the various factor inputs used for production. Due to the cross-sectional variation in these quantities, the energy consumption practices of industry are very locationally dependent.

The third and final related decision is the choice of energy form (coal, oil, natural gas, or electricity) to be used. Here again, one would expect a "cost minimization" to take place, with the fuel form that is perceived to exhibit the lowest discounted capital and operation costs chosen to meet the energy input requirements.

The model we have selected to describe the behavior of industrial energy consumption is designed to separate out and capture the simultaneous interaction of the three decisions. Our first equation relates total energy requirements for the industrial sector, at an aggregated level, to the price of energy and to value added in manufacturing, the measure of economic activity used[4]. The second set of equations attempts to explain the influence of cross-sectional variation in various factor inputs, specifically, the cost of energy, on where energy is consumed. The final set of equations incorporates the substitution possibilities between alternative fuel forms in response to changing prices. Figure 3 depicts the three level decision model used for these analyses. The following three sections describe the specification and estimation of each of these three components.

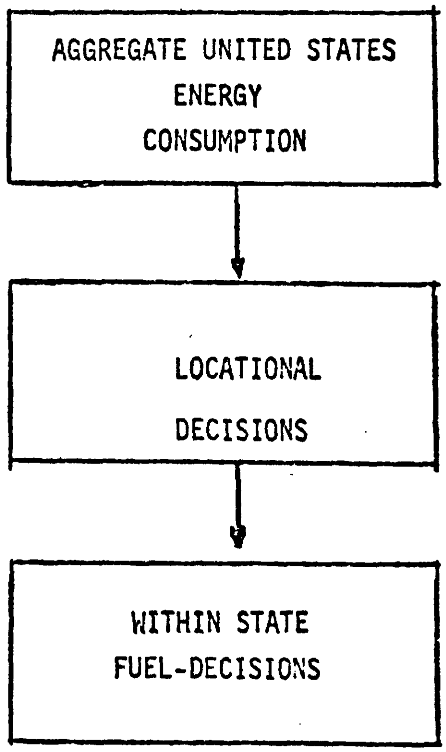

FIGURE 3

[4] Ideally the derived demand for energy should be a function of energy prices, output, wages, and the cost of capital services. We have attempted to include wage rates in the estimating equations, but this series is highly correlated with the price of energy, making the identification of individual coefficients impossible. We are constructing a cost of capital series using the Hall-Jorgenson [6] approach which we plan to include in future estimating equations.

II.1 TOTAL U.S. ENERGY DEMAND IN THE INDUSTRIAL SECTOR

The first equation of the three-level decision process deals with total industrial energy input demand for the aggregate United States. In this part of the model, the intent is both to incorporate the energy/non-energy substitution possibilities that exist in the aggregate industrial production function of the U.S. and to capture the scale effect (i.e. the amount of energy requirements as a function of both its price responsiveness and industrial activity). In this regard, our relationship is similar in intent to that of Jorgenson [7] and Hnyilicza [8], although it does not span the entire mix of factor input alternatives as is done in these works. This equation has been estimated using aggregate time series data. While cross-sectional data exist, the direct estimation of demand functions using such data presents certain important problems. The variation in energy consumption across states for particular industries reflects both pure substitution effects as well as locational effects across the states. Our aim here is to disentangle these effects.

The independent variables used to explain industrial energy demand are the average price[5] to the industrial sector and value-added in the manufacturing sector[6].

In mathematical terms, the equation used is

$$(1) \quad TIE = f(VAM, PAVE)$$

where

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5 See the appendix for a discussion of the derivation of average price.

6 "Manufacturing sector" is to be distinguished from "Industrial sector" since it is known that our price and consumption figures include such industry as mining, construction and agriculture, but that our value-added totals do not include these, since their value-added figures are available only sporadically.

TIE = total industrial energy consumption in the U.S. (BTU's)

VAM = value-added in manufacturing (1967 constant dollars)

PAVE = average price of energy consumed in the U.S. in the industrial sector (1967 constant dollars).

A priori, one would not expect lagged adjustments in energy consumption to changes in value-added because sudden increases or decreases in production would be reflected immediately in energy utilization patterns. One would nevertheless expect a lagged response to changes in energy price since the purchase and disposal of plants and machinery to accommodate different levels of energy input per unit of output is not a short term phenomenon.

Three basic types of lagged response were estimated. In the first case, the prices were entered in an ordinary distributed lag form. However, due to the high degree of multicollinearity among the lagged prices, the results were unacceptable. Since an Almon lag specification would only worsen the multicollinearity problem, a geometrically declining lagged response was imposed on the price term with a Koyck-lag. In this case the equation is structured so that the influence of changes in value-added are immediate in their effects on consumption, but adjustments to changes in price are geometrically distributed over time. The estimated results were:

$$\mathrm{Log(TIE)}^t = A + B * \mathrm{Log(PAVE)}^t + C * [(\mathrm{Log(VAM)}^t - D * \mathrm{Log}\ (\mathrm{VAM})^{t-1}] + D * \mathrm{Log}\ (\mathrm{TIE})^{t-1}$$

RANGE = 1948 to 1972 CRSQ = .974 DW = 1.83 F(3/21) = 292.690

COEF	VALUE	T-STAT
A	14.1	2.34
B	-.154	-1.04
C	.628	13.6
D	0.218	1.00

The estimated coefficient of the lagged dependent variable in this case is very small. A value of .218 implies an adjustment time of considerably less than two years, and in addition, it is not significant (t-statistic= 1.0). The price coefficient (also lacking significance) implies a long run elasticity of about -0.2. The results of this equation seem to indicate a lack of lagged response, so our only alternative was to estimate an equation without any imposed lagged structure.

The third form estimated, therefore, assumes no lagged adjustment processes. Since with ordinary least squares estimation the presence of first order serial correlation was detected, the results, presented in Figure 4, have been estimated with a technique that nets out a first-order autoregressive process[7]. Both Durbin-Watson statistics indicate that at the 5% level the serial correlation formerly present has been removed.

The results are reported for two time periods, 1950-1967, and 1950-1972, so that we can test to see if natural gas shortages are biasing the estimates in the longer time interval. The results indicate there is little difference in the estimates between the two time periods. The estimated price elasticity is about -0.25, the estimated value-added elasticity is about +0.65, and the coefficient of price is still not significant at the 5% level for either equation.

At this point, we are faced with the prospect of either utilizing this result even though price is not statistically significant, or dropping price out of the equation and concluding that the price elasticity in the industrial sector is zero. Either way, the price elasticity of total industrial energy demand is very small.

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[7]The technique was based on an iterative search procedure for the serial correlation coefficient that minimized the sum of squared residuals. See reference [9] for a more complete description.

ESTIMATION RESULTS FOR TOTAL U.S. INDUSTRIAL ENERGY DEMAND

1950 - 1972

$$\text{Log TIE} = \underset{(4.48)}{15.70} - \underset{(-1.13)}{0.219} \text{ Log (PAVE)} + \underset{(16.05)}{0.688} \text{ Log (VAM)}$$

$R^2 = 0.953$ F= 204 DW = 1.88

1950 - 1967

$$\text{Log TIE} = \underset{(4.90)}{15.78} - \underset{(-1.51)}{0.280} \text{ Log (PAVE)} + \underset{(17.32)}{0.652} \text{ Log (VAM)}$$

$R^2 = 0.963$ F = 207 DW = 1.96

TIE = Total U.S. energy consumption for industrial sector (less petrochemical uses)

PAVE= Deflated average price of fuels consumed

VAM = Deflated value-added in Manufacturing

FIGURE 4

II.2 LOCATIONAL EFFECTS

The second set of equations of our industrial energy demand model deals with where energy is consumed among the individual states, and implicitly deals with industrial decisions to move to or remain in a particular state. The output of this part of the model is the fraction of total U.S. industrial energy demand that each state comprises.

The United States is broken down into forty-nine locations for this analysis -- D. C. and all the states except Alaska and Hawaii[8]. We use a logit formulation to relate the cross-sectional configuration of energy consumption to industry's preference for various state-specific attributes. (For a further discussion of the theory and properties of the conditional logit model, see reference [2]). The energy consumption (E) for state i at time t can then be written as:

$$(2) \quad E_i^t = \left(\frac{e^{I(X_i^t)}}{\sum_{i=1}^{49} e^{I(X_i^t)}} \right) * TIE$$

where

TIE is the total U.S. industrial energy consumption
E is the total demand for energy
X is a vector of state-specific attributes and
$I(X_i^t)$ is the choice index for state i.

[8]Alaska and Hawaii are excluded from the sample because data for the total demand equation excluded them.

If we divide both sides of (1) by TIE, we obtain a more conventional share formulation:

$$(3a) \quad F_i^t = \left(\frac{e^{I(X_i^t)}}{\sum_{i=1}^{49} e^{I(X_i^t)}} \right)$$

where

$$F_i^t = \frac{E_i^t}{TIE}$$ = fraction of total U.S. industrial energy consumption in state i at time t.

and where, by definition,

$$(3b) \quad \sum_{i=1}^{49} F_i^t = 1.0$$

It is this specification (3(a) + 3(b)) that we use for this part of the model.

There are many properties that can be considered as state specific attributes (X_i^t). An industry locates in a particular state because of low fuel prices, cheap raw materials, ease of transportation, proximity to related industry, the availability and costs of labor, etc. The selection of appropriate state attributes is complicated at first by the fact that many possible regressors are more the result than the cause of industry's location. For instance, value-added in manufacturing and the number of manufacturing employees measure industrial activity already in a given state, but these variables are not really a measure of the inherent attractiveness of a state for industrial location. What is desired for this part of the model are variables that are state specific and unambiguously descriptive of those characteristics an industrial customer would consider in a locational decision.

For testing the locational hypothesis, two regressors were chosen. The first is a weighted fuel price for each state (constructed by weighting each fuel price by its market share in the state) and the second is the population of the state (chosen for its indication of the size of the potential labor force). The first is a measure of the cost of energy inputs, the second is a measure of the availability of labor inputs. ("Population" is preferred here to "number of manufacturing employees" because it is only indirectly connected with the production of manufacturing goods and the amount of industry already in existence[9]). Though the cost of capital services in any state is relevant to industry's production decisions, it was not felt that the cost would vary significantly from state to state or would thus influence industry's geographical movements.

Though industry might decide to locate in a particular state on the basis of the state's current price and population, it does take time for industry to make a move and re-establish its energy consumption trends. To account for this we utilize a partial adjustment model, i.e., we assume that the change in state fuel shares is proportional to the difference between existing shares and those desired. If the desired state shares at time "t" are designated as $F_{i,t}^{*}$ (where the desired values are a function of the current period price and population configuration only) then the adjustments are modeled to take place according to the following equation:

$$\ln\left(\frac{F_{i,t}}{F_{j,t}}\right) - \ln\left(\frac{F_{i,t-1}}{F_{j,t-1}}\right) = \lambda\left[\ln\left(\frac{F_{i,t}^{*}}{F_{j,t}^{*}}\right) - \ln\left(\frac{F_{i,t-1}}{F_{j,t-1}}\right)\right]$$

with λ being the proportionality constant. If we assume that the

[9] The population variable does have other problems, however, namely, that people will be attracted to the location of industry.

choice index for state "i" can be written as:

$$I(X_i^t) = B * \text{Log}(PS_i^t) + C * \text{Log}(PoP_i^t)$$

where

PS_i^t is the weighted average price for each state i at time t.

PoP_i^t is the population of state i at time t.

then the log-odds form of equation (3a) can be written as:

$$\text{(4a)}\quad \text{Log}(F_i^t/F_j^t) = B * \text{Log}\left(\frac{PS_i^t}{PS_j^t}\right) + C * \text{Log}\left(\frac{PoP_i^t}{PoP_j^t}\right) + + D * \text{Log}\left(\frac{F_i^{t-1}}{F_j^{t-1}}\right)$$

In the presence of serial correlation, ordinary least squares estimation of (4a) will yield inconsistent esimates 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

[10]See Reference [10]. Estimation with 5 or 6 years of data (1962-1967, 1968-1972) leaves only 4 or 5 observations with which to estimate a serial correlation coefficient for each state with the Balestra and Nerlove technique.

It was felt that, with so few time observations, the error-components technique of Balestra and Nerlove might even yield estimates worse than OLS.

technique for obtaining consistent estimates is to use an instrumental variable estimating technique in combination with separate dummy variables for each state. However, because of the small relative movements in actual state shares over the period of our data, the inclusion of state dummy variables merely explains with a set of constants the state fractions. For this reason we did not use the separate state dummies. We have, however, applied a two-stage least-squares estimating technique to obtain consistent estimates. We have also utilized a weighting procedure to remove heteroscedasticity bias.

The heteroscedasticity adjustment is necessary because, if one assumes that the consumption of fuel in any state is proportional to the number of individual decisions made in favor of that state, then the variance of the observed mean frequency (state share in this context), is proportional to the reciprocal of the number of decisions made. 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 the number of decisions included in the observation[11]. For this case this number is proportional to the square root of the sum of the consumption of the two states in each of the log-odds ratios. This weighting procedure was used throughout in the estimation of the state-split equations as well as in the similarly formulated set of fuel-split equations described in the next section.

The sample period for the estimates are 1962-1967 and 1968-1972. A priori, one would expect the coefficient of price to be negative, the coefficient of population to be positive, and the coefficient of the lagged dependent variable to be positive and somewhere between 0.9 and 1.0, due to the time required for locational adjustment. The estimated results for both time periods are presented

[11] See Reference [11], pp. 174-177

in Figure 5[12].

The major difference in the estimates over the two time periods is the size of the coefficient of the lagged dependent variable, or, since the size of this variable determines the time required for adjustment, the length of the adjustment process. The time required for 90% adjustment in equation (5a) is 26 years, while in (5b) it is well over 50 years! Apparently over the 6 year period 1962-1967 there was so little change in the geographic patterns of energy consumption that the changes and the motivating influences were, for all practical purposes, inestimable. By the late sixties and early seventies, however, it is a fact that there was more movement in energy prices (in real terms) than in any comparable period for the previous twenty years. For this reason, we feel the estimates for the period 1968- 1972 to be more reliable.

Since the long run price elasticity for both equations is quite high, with a value of -2.0 in equation (5a) and -2.5 in equation (5b) the question is not, what is the magnitude of the long run response (in both cases it is high), but rather, how long is long run. A priori, 25 years seems much more reasonable in this context.

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[12]Another form of equation (4a) was also estimated. Here we tested whether the costs of labor (measured using average wage rates of manufacturing employees) play a significant role in the locational decision. The estimated results (with W_i signifying wage rates in state i) were:

$$\log\left(\frac{F_i}{F_j}\right) = B * \text{Log}\left(\frac{PS_i}{PS_j}\right) + C * \text{Log}\left(\frac{PoP_i}{PoP_j}\right) + D * \text{Log}\left(\frac{W_i}{W_j}\right) + E * \text{Log}\left[\frac{F_i^{(-1)}}{F_j^{(-1)}}\right]$$

	COEFFICIENT	T-STAT
B	-0.167	-5.19
C	0.051	3.15
D	0.042	0.63
E	0.916	49.9

R^2 = .983 F = 4574 RANGE = 1968-1972

The coefficient of wages is insignificantly different from zero, and thus, the hypothesis could not be accepted.

STATE ALLOCATION EQUATION

1968 - 1972

EQUATION (5a)

$$\text{Log}\left(\frac{F_i}{F_j}\right) = -0.17\ \text{Log}\left(\frac{PS_i}{PS_j}\right) + 0.054\ \text{Log}\left(\frac{PoP_i}{PoP_j}\right) + 0.916\ \text{Log}\left(\frac{F_i^{t-1}}{F_j^{t-1}}\right)$$

(-5.18) (3.44) (49.9)

$R^2 = 0.983$ F= 240

1962 - 1967

EQUATION (5b)

$$\text{Log}\left(\frac{F_i}{F_j}\right) = -0.034\ \text{Log}\left(\frac{PS_i}{PS_j}\right) + 0.013\ \text{Log}\left(\frac{PoP_i}{PoP_j}\right) + 0.987\ \text{Log}\left(\frac{F_i^{t-1}}{F_j^{t-1}}\right)$$

(-1.40) (1.06) (72.9)

$R^2 = .994$ F = 20,800

where:

PS_i is the weighted average price for each state i.

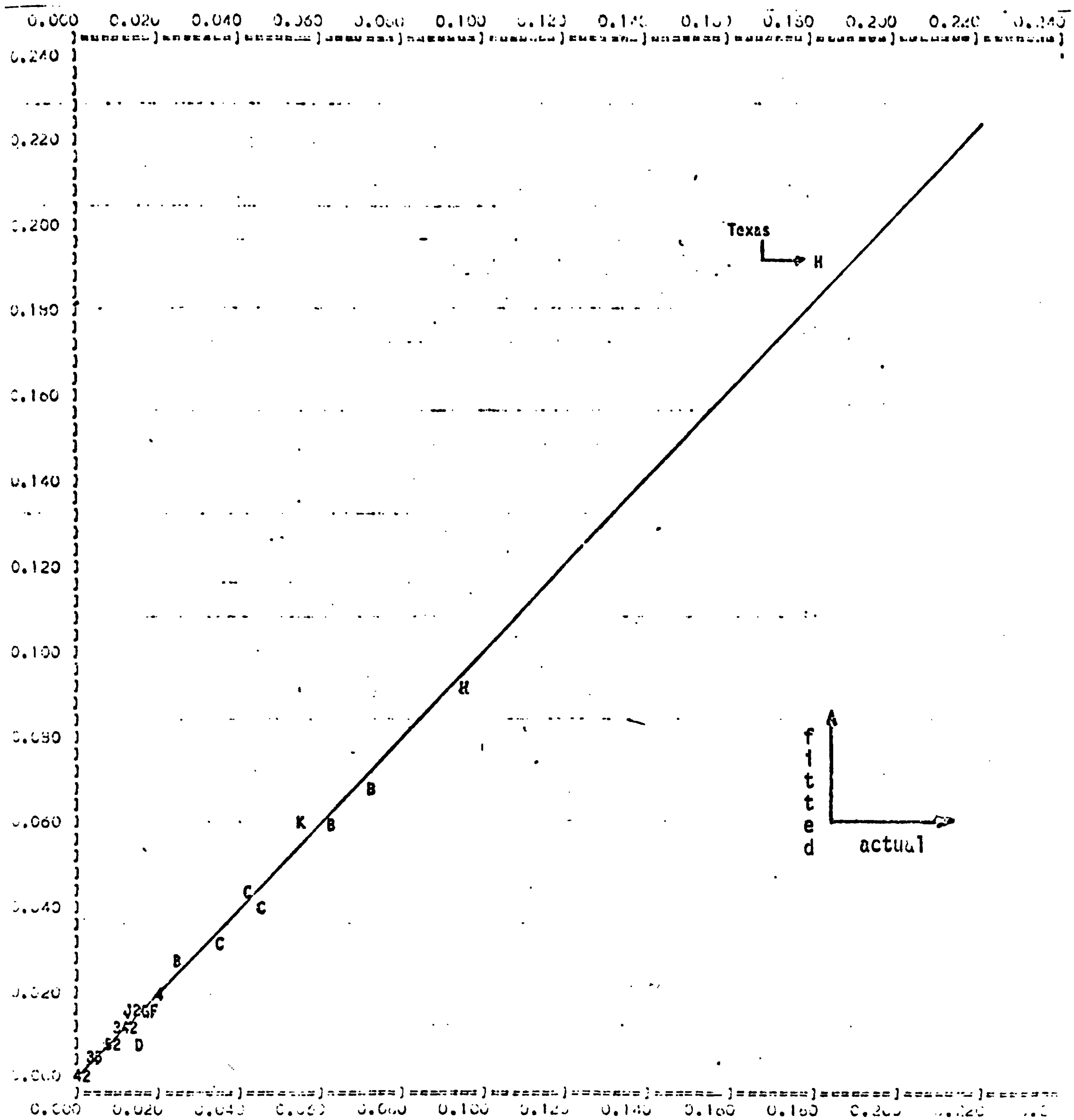
PoP_i is the population of state i.

t-1 superscript indicates a one period lag.

i and j subscripts denote the i^{th} and j^{th} states

F I G U R E 5

Even though this elasticity is quite high, it is not inconsistent with historical trends in industrial development. Figure 6 displays a plot of actual vs. fitted results for 1972, and there it can be seen that just nine states have significantly greater than 2% of total U.S. consumption, and that Texas, the state historically with the lowest energy prices, comprises by itself about 18% of total U.S. consumption. With the recent reordering in cross-sectional energy costs, these results have most important implications for future geographical patterns of industrial development.



STATE SPLIT-EQUATION - 1972

(Actual vs. Fitted)

FIGURE 6

II.3 FUEL CHOICE DECISIONS

The third and final set of equations of the model are the fuel choice relationships. Total demand for industrial energy, having been determined for the country and distributed among the states, is now split by fuel within the states. As in our previous work in the residential-commercial sector, the conditional logit formulation of fuel choice is used.

The main explanatory variables used in this part of the model are the four fuel prices. We would have liked to have also included the cost of different fuel consuming equipment; however, the information needed to construct a series of this nature was unavailable[13].

Similar to the formulation discussed in the previous section, the basic model for the fuel split relationships in the log-odds form can be written as:

$$(6a)\quad \begin{cases} \log\left(\frac{S_g}{S_e}\right)^{s,t} = A_1 + B*\log\left(\frac{PG}{PE}\right)^{s,t} + C*\log\left(\frac{S_g}{S_e}\right)^{s,t-1} \\ \log\left(\frac{S_o}{S_e}\right)^{s,t} = A_2 + B*\log\left(\frac{PO}{PE}\right)^{s,t} + C*\log\left(\frac{S_o}{S_e}\right)^{s,t-1} \\ \log\left(\frac{S_c}{S_e}\right)^{s,t} = A_3 + B*\log\left(\frac{PC}{PE}\right)^{s,t} + C*\log\left(\frac{S_c}{S_e}\right)^{s,t-1} \end{cases}$$

---

[13] It is unlikely that these values are correlated with other included independent variables so that the misspecification should not result in biased estimates. It is also unlikely that there is very much cross-sectional variation in these capital costs.

$S_g^{s,t}$ = Market share of gas in state s at time t.

S_o = Market share of oil.

S_c = Market share of coal.

S_e = Market share of electricity.

PG = Price of gas.

PO = Price of oil.

PC = Price of coal.

PE = Price of electricity.

$A_1 - A_3$, B, and C = estimated coefficients

where again, as indicated by the lagged dependent variables in equation (6a), we assume a partial adjustment model.

Equations (6a) and (6b) were estimated with the same techniques used for the state-split equations. Like the state-split equations, where the coefficients of like attributes were constrained to be the same over all states, in the fuel equations the coefficients of the fuel attributes (prices) are constrained to be the same over all fuels. Unlike the state-split equations, however, we use a different constant term for each fuel to capture unspecified differences in technique attributes, such as differences in capital costs, cleanliness, etc[14].

The estimation results for equation (6a) are presented in

[14] See Ref. [2] for further discussion of these autonomous "technique specific" effects.

Figure 7[15,16]. The price term is significant at the 1% level in both

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[15] Attempts have been made to separate the responsiveness to fuel price in the various types of industries. This was done by multiplying the various constant terms and prices by two fractions summing to one -- one for the eight most energy-intensive industries of Figure 1 and one for all the rest, constructed by taking the ratio of the value-added for two collectively exhaustive groups of the two-digit SIC breakdown with total value-added in the manufacturing sector. The results were:

VARIABLE	COEFFICIENT (T-Stat) Intensive Sectors		COEFFICIENT (T-Stat) Non-Intensive Sectors	
Gas-Elec. Constant	-0.02	(-0.03)	-0.65	(-3.72)
Oil-Elec. Constant	0.01	(0.04)	-0.85	(-5.60)
Coal-Elec. Constant	-0.39	(-1.34)	-0.91	(-5.02)
Price $[\log(P_i/P_j)]$	-0.26	(-1.99)	-0.43	(-5.30)
Lagged Dependent Variable 0.83 (54.97)				
RANGE = 1968 - 1972	R^2 = 0.968		F(8/726) = 2813	

The results yield about 60% higher elasticity of substitution for the non-energy intensive industry grouping than for the energy-intensive industries. This indicates that the energy-intensive industries are probably more locked into specific fuel forms for their processing needs.

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[16] Another specification which allowed for different price responsiveness for each fuel form was also estimated. This was done because, in reality, we know that the fuels, since they are not perfect substitutes do not necessarily possess the same elasticity of substitution as the conditional logit formulation in the text assumes. The estimation was done by allowing the coefficient of each price term in equation (6a) to be different. The estimated results were:

VARIABLE	COEFFICIENT (T-Stat)	
Gas-Electricity Constant	-1.47	-1.95
Oil-Electricity Constant	3.52	1.49
Coal-Electricity Constant	-3.10	-1.54
Gas Price	-0.38	-7.55
Oil Price	-0.02	-0.14
Coal Price	-0.47	-3.42
Electricity Price	0.30	6.19
Lagged Dependent Variable 0.83 (65.4)		
RANGE = 1968 - 1972	R^2 = .968	F(7/727) = 3184.

ESTIMATION RESULTS, FUEL-SPLIT RELATIONSHIPS

1968 - 1972 COEFFICIENT	VALUE	T-STAT
A_1	-0.357	-4.89
A_2	-0.489	-7.14
A_3	-0.650	-7.93
B	-0.323	-8.03
C	+0.844	59.9
R^2 = 0.968	F = 5539.	

1962 - 1967		
A_1	-0.043	-1.10
A_2	-0.160	-4.52
A_3	-0.143	-3.00
B	-0.083	-2.66
C	+0.94	92.1
R^2 = 0.982	F = 10,100	

F I G U R E 7

COEFFICIENTS DEFINED IN EQUATION (6a)

equations. Again, the major difference between the two periods' estimates is the coefficient of the lagged dependent variable. The period 1968-1972 (as in the state-splits) again yields higher short-run elasticities and shorter adjustment times. For 1968-1972 the estimated time required for 90% adjustment is about 14 years, whereas for the period 1962-1967 the implied adjustment time is over 30 years. Based upon priors, 14 years seems to be more realistic, especially now that fuel prices have seen abrupt change in recent months.

The values of the constant terms indicate that, aside from price, the industrial sector prefers first electricity, secondly gas, then oil and finally coal. If all fuel prices were set equal, the mix of industrial fuels consumed would tend toward market shares of 35% electricity, 25% gas, 21% oil and 18% coal.

The long-run elasticity of substitution between the fuels is estimated to be about -2.0 for 1968-1972 and -1.7 for 1962-1967. Both values are quite large. Interestingly enough, the earlier period exhibits the lower elasticity, counter to what you would expect if gas shortages removed price as an effective decision instrument.

To better show the importance of prices, Figure 8 displays the average price elasticity matrix of market shares[17] for both the short and long run calculated from the 1968-1972 estimates. The cross-terms indicate that consumption "switched" in response to a change in a given fuel's price is switched to the alternative fuels in proportion to their already existing market shares (hence, equality of the off-diagonal terms in each column). For comparison to our results in the residential-commercial sector, Figure 8 also shows the equivalent

[17] The market share elasticities should not be confused with the elasticities of demand for each of the fuels. One has to account for locational and total sector price effects before we have a true demand elasticity for any given fuel. In the next section the entire model is used to derive a set of fuel elasticities.

long run matrix for that sector.

Finally, it should be noted that the matrices displayed in Figure 8 are average U.S. elasticities, derived using U.S. market shares. In reality the elasticities vary from state to state. To compute them for any state one need only use the appropriate state market shares. To give an indication of the variation of market shares and at the same time to illustrate the quality of the estimated relationships, Figures 9-12 show plots of the actual vs. fitted market shares on a state by state basis for 1972.

AVERAGE MARKET SHARE ELASTICITIES

IN THE INDUSTRIAL SECTOR

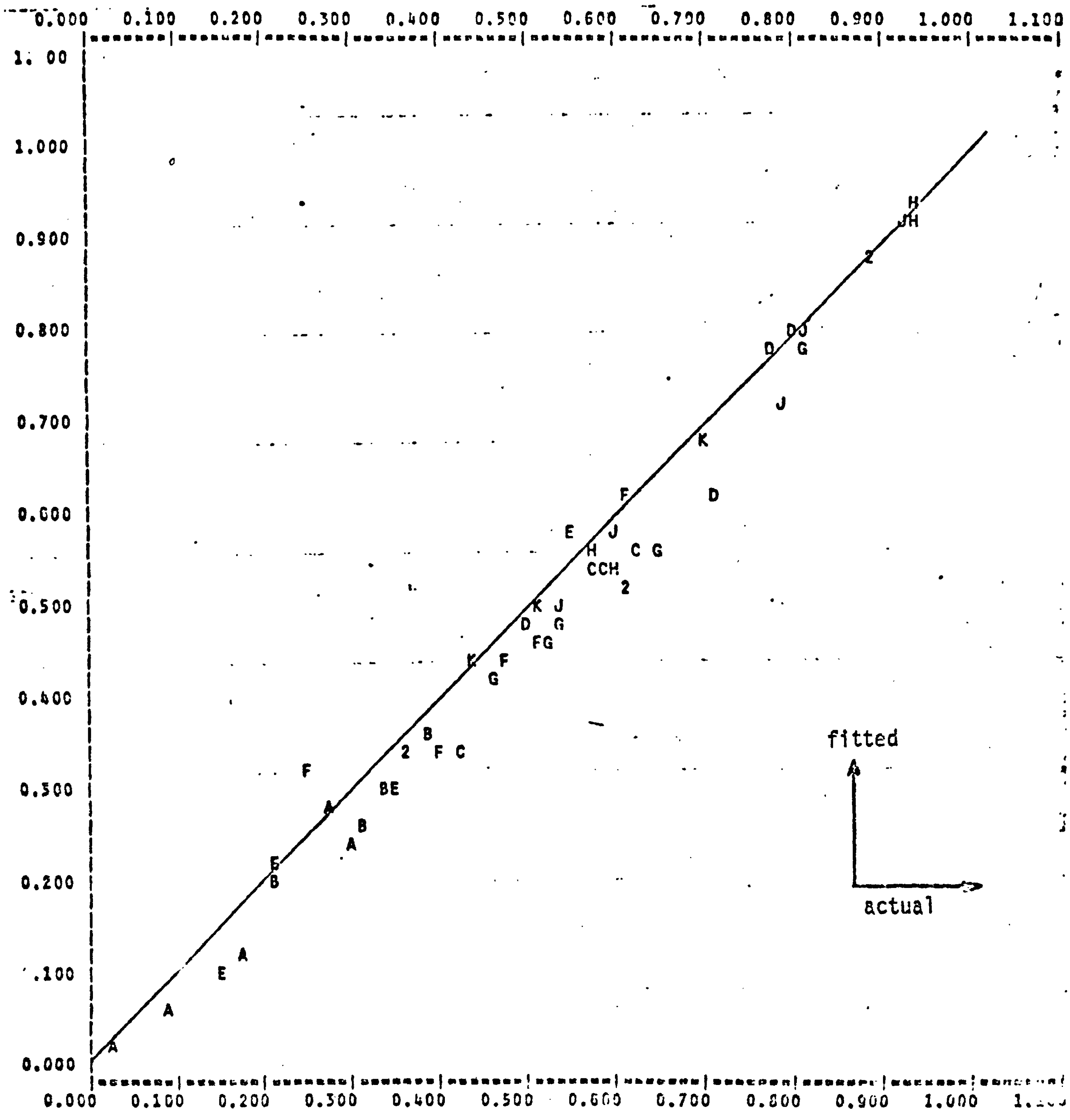
Short-Run (S R)
Long-Run (L R)

		P_g	P_o	P_c	P_e
S_g	S R	-0.16	0.04	0.07	.04
	L R	(-1.02)	(0.26)	(0.45)	(0.26)
S_o	S R	0.17	-.28	0.07	.04
	L R	(1.09)	(-1.79)	(0.45)	(-.26)
S_c	S R	0.17	0.04	-0.25	.04
	L R	(1.09)	(0.26)	(-1.60)	(0.26)
S_e	S R	0.17	0.04	0.07	-.28
	L R	(1.09)	(0.26)	(0.45)	(-1.79)

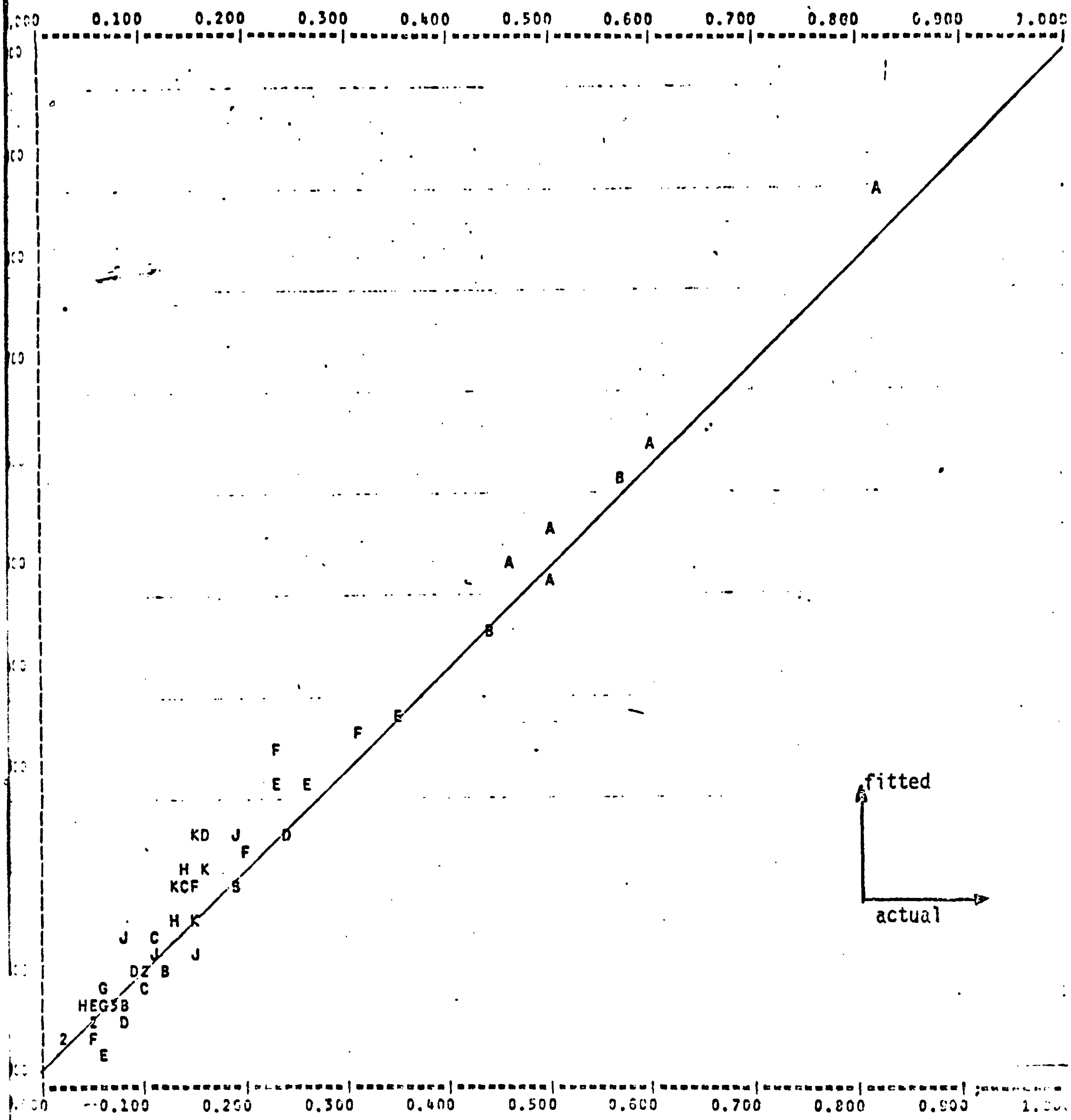
RESIDENTIAL and COMMERCIAL

		P_g	P_o	P_e
S_g	L R	-.545	.187	.194
S_o	L R	.555	-0.390	.194
S_e	L R	.555	.187	-.755

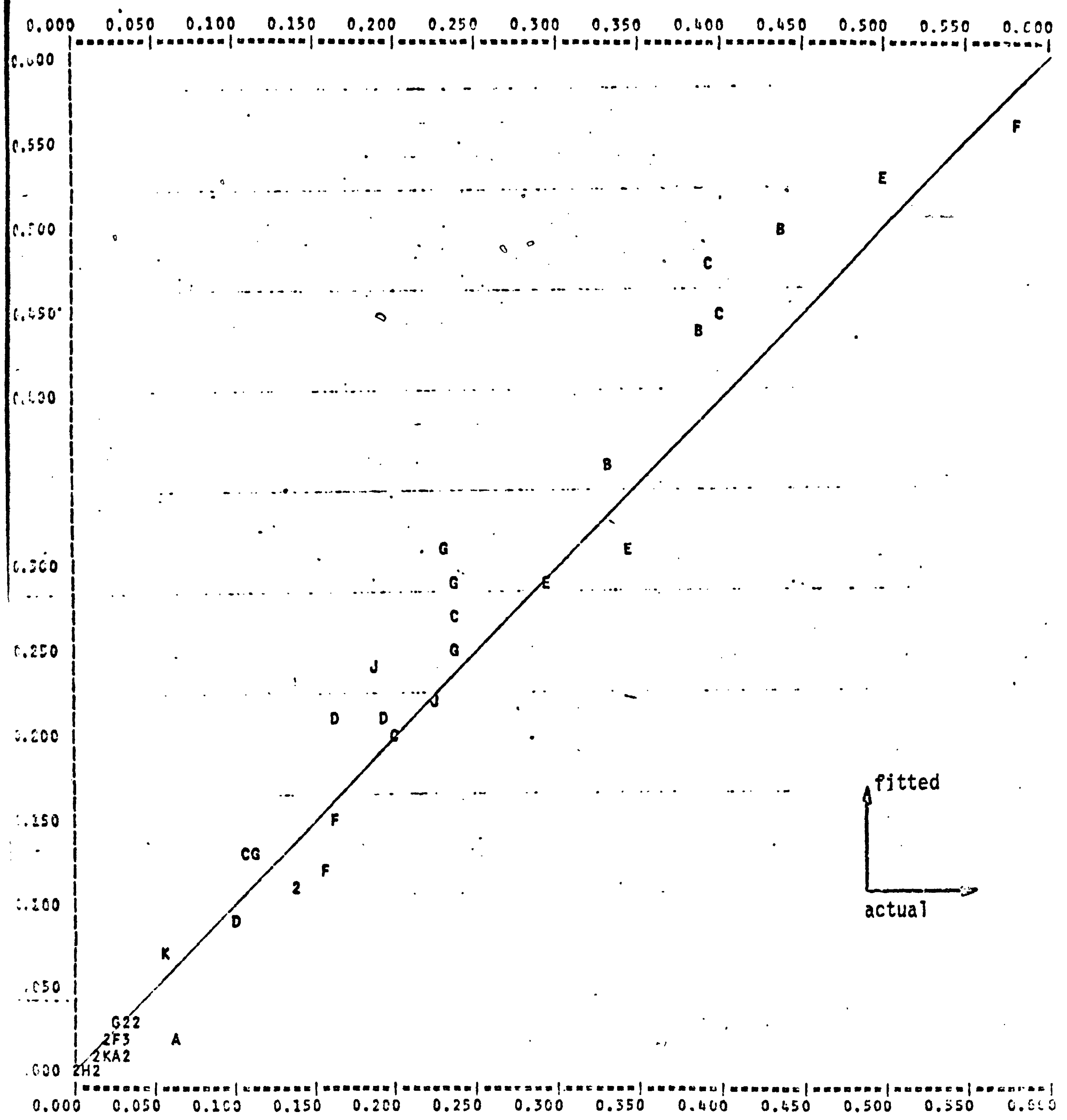
FIGURE 8



NATURAL GAS -- 1972
(Actual vs. Fitted)
Market Shares
FIGURE 9



O I L - 1 9 7 2
(Actual vs. Fitted)
Market Shares
FIGURE 10

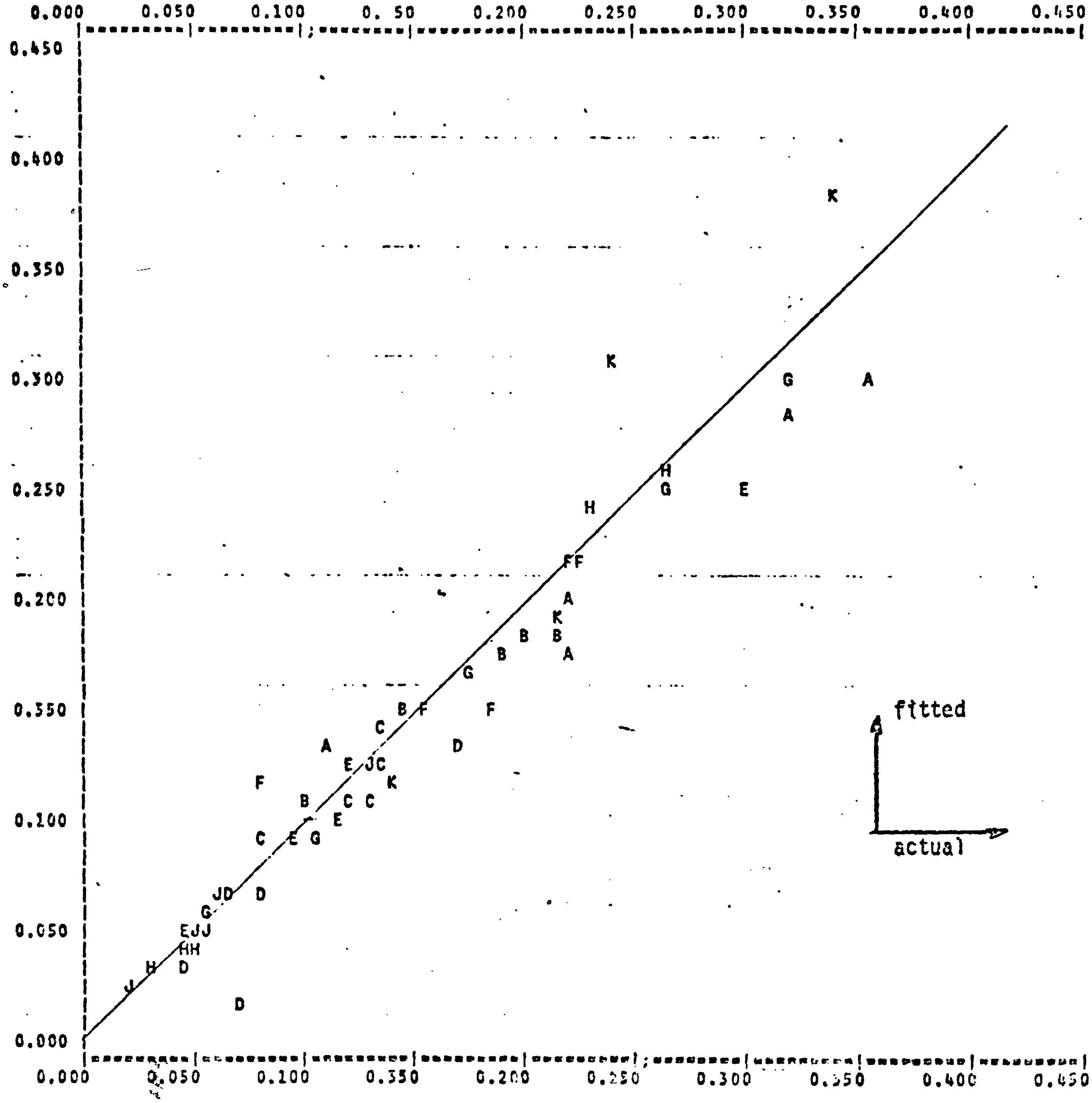


C O A L - 1 9 7 2

(Actual vs. Fitted)

Market Shares

FIGURE 11



ELECTRICITY -- 1972
(Actual vs. Fitted)
Market Shares

FIGURE 12

III. ANALYSIS WITH THE MODEL

In the previous sections we have described our model for industrial energy and fuel demands. In this section the model is utilized to compute a matrix of fuel demand elasticities and to project the future demand for fuels in the industrial sector from now to the year 1985 for a set of alternative assumptions about future fuel prices.

The Elasticities

Recall that the model incorporates equations for three simultaneous decisions. The first is an equation for total energy demand (excluding feedstocks) of the industrial sector in the U.S. The second is a set of equations used to derive the cross-sectional energy consumption patterns by state. The final equation is used to derive demands for each of the four specific energy forms in each state. Since all levels of the model simultaneously utilize information on fuel prices (directly in the fuel-splits, indirectly through weighting in the state-split and total energy demand equations) it is difficult to compute analytically all the elasticities discussed in section II and obtain a set of price-elasticities for each of the fuels in the model. They can be easily obtained, however, through simulation.

Figure 13 presents the short-run (one-year) and long-run elasticities for each form of energy included in the model. These have been derived via simulation by altering individually the prices of each energy form (by 5%), and then using the simulated results one year and twenty years after the change to compute the relevant fuel price elasticities. This was done around a trajectory of prices corresponding to those used by the F.E.A. for their $7/Bbl. analyses (See Ref. [5], pg. 69). The results indicate that the long-run self-

SUMMARY FUEL ELASTICITIES

INDUSTRIAL		P_g	P_o	P_e	P_c
GAS	SR	-.07	.01	.03	.01
	LR	-.81	.14	.34	.15
OIL	SR	.06	-.11	.03	.01
	LR	.75	-1.32	.34	.14
ELECTRICITY	SR	.06	.01	-.11	.01
	LR	.73	.13	-1.28	.14
COAL	SR	.06	.01	.03	-.10
	LR	.75	.14	.33	-1.14

FIGURE 13

elasticities of demand vary from -.81 to -1.32. The highest value corresponds to oil at 1.32, followed very closely by electricity at -1.28, coal at -1.14, and the lowest value for gas at -.81. The long-run cross-elasticities vary from + 0.13 to 0.75.

The highest cross-elasticity exists for changes in natural gas price and the lowest for changes in oil prices, exactly the opposite of the relative magnitudes for the self-elasticities. This is due to the present configuration of fuels consumption in this sector in combination with the relative total demand and substitution elasticities that were estimated in the previous section. In Section II, the elasticity of total U.S. industrial energy demand was estimated to have a value of -0.2, while the substitution elasticity between fuels was estimated to have a value of about -2.0. Consequently, with a change in a given fuel's price, the relative substitution, or fuel-switching, response is about 10 times as large as the total demand for energy response in this sector. If a fuel comprises a large percentage of the market, then a change in consumption of that fuel, when distributed to the remaining fuel categories, represents a high percentage change in the consumption of those alternative fuels. In 1972, natural gas represented over 50% of the energy consumption in the industrial sector. Due to this configuration the cross-elasticities for natural gas are much higher than for the alternative fuels. Similar reasoning explains the relatively lower self-elasticity of natural gas. In all cases, the short-run elasticities are about one-twelfth of the long run, indicating a 12 year adjustment time.

To fully appreciate these numbers, however, one must realize that they are applicable only to the nation as a whole. In actual fact each state has a different set of elasticities that are a function of the presently existing market shares of each fuel and the relative fuel prices. Our model implicitly incorporates these differences in the simulation mode. Figure 13 exhibits only the national responses.

THE SIMULATIONS

We report three simulations of the model corresponding to three possible future states of the world. The first two cases to be presented are directly comparable in assumptions to two cases reported in the Project Independence Report [5] by the Federal Energy Administration. The final case presented is an extrapolation of fuel costs beyond 1972 through 1985 assuming that the sharp rise in fuel prices accompanying the Arab Oil Embargo did not occur. In all cases it is assumed that real value-added grows at 3.7% per year and population grows at 1.02% per year in all states.

The fuel prices used in these simulations are given in Figure 14. The fossil fuel prices for Case I and II correspond to those reported in the Project Independence Report (ref. [5], pp. 69). for $7 and $11 per barrel oil in the "Business as Usual" scenarios. The electricity prices were computed from a model of electricity supply and demand, constructed and reported elsewhere[18], for the fossil fuel price configuration of Case I. For Case III we assume O.P.E.C. never came into existence and that after 1972 the costs of fossil fuels increased at a real rate of 2% per year. The electricity prices were obtained from the same electricity model using the assumptions about fossil fuel costs for this case.

For simulation purposes, the average wholesale prices are used as indices to obtain price movements for each state at the point of consumption. The refining, transportation, and distribution markups are assumed to remain constant in real terms over the period.

The simulation results for the entire U.S. are presented in Figure 15, with the actual 1972 consumption figures and the forecasts for the $7 and $11 per barrel cases (Cases I and II) derived by the

[18]See Reference [12].

REAL PRICES (1974 dollars) USED FOR SIMULATIONS

	Oil Price ($/Bbl)	Natural Gas Price (¢/MCF)	Coal Price ($/ton)	Electricity Price (¢/Kwhr.)
CASE I - F.E.A. $11 per barrel				
1975	6.70	64.2	10.44	2.39
1980	10.34	64.2	10.44	2.46
1985	10.86	64.2	10.44	2.27
CASE II - F.E.A. $7 per Barrel				
1975	5.50	64.2	10.44	2.39
1980	7.00	64.2	10.44	2.46
1985	7.00	64.2	10.44	2.27
CASE III - No O.P.E.C. (2% per year real increase)				
1975	4.16	62.4	7.80	1.96
1980	4.59	68.9	8.62	1.99
1985	5.07	76.1	9.52	1.87

FIGURE 14

Oil is average price at the wellhead
Gas is average price at the wellhead
Coal is average price at the minemouth
Electricity is average price per kilowatt-hour consumed

F.E.A. The F.E.A.'s forecasts are an interesting comparison because they were derived from a model similar in construction.

Several things should be noted about the comparison between our model and the F.E.A.'s, however, before discussing the numerical results. The F.E.A. uses Bureau of Mines (B.O.M.) accounts for determination of consumption in the industrial sector. The main difference is that feedstocks, or raw material uses, have been excluded from our data, but are included in the B.O.M.'s data and the F.E.A.'s model. Petroleum for raw material use was 3.4 quadrillion BTU's (quads) in 1972. This accounts for the disparity between the B.O.M.'s and our oil consumption data in 1972 shown in Figure 15. Also, the Bureau of Mines reports electricity consumption in 1972 as 2.5 quadrillion BTU's, compared to 2.2 for us. The reason for this disparity is unclear because the Bureau of Mines indicates that it uses Edison Electric Institute sales data to derive their number and we use the same. Apparently the Bureau of Mines must include some losses in their sales to arrive at the 2.5 quadrillions. A further disparity also exists in coal. Part of this difference again is that the Bureau of Mines, and thus the F.E.A., includes coal for raw material uses in its data (about 0.1 quads); but the major difference is accounted for by the BTU's conversion factors used to derive the numbers in Figure 15 from actual sales units (in tons). Whereas the B.O.M.'s uses about 26.8 million BTU's per ton for industrial coal, we use the electric utility conversion factors which average about 22 million BTU's per ton. Consequently, all our coal numbers need to be multiplied by 1.22 to be comparable to the F.E.A.'s. Finally, our gas consumption number is slightly higher than the F.E.A.'s in 1972. This is because we include "lease and plant fuel" in the industrial consumption category, while this has been excluded by the F.E.A.

U. S. SIMULATION RESULTS*

Quadrillions of BTU's

Industrial Sector

	TOTAL	GAS	OIL	ELECTRICITY	COAL
1972 Actual (F.E.A.)	23.0	10.6	5.7	2.5	4.3
Actual (Our Model)	19.7	11.8	2.1	2.2	3.5
1975 CASE I (Our Model)	18.6	11.8	2.0	2.5	2.3
CASE II (Our Model)	18.7	11.7	2.1	2.5	2.3
CASE III (Our Model)	19.1	11.6	2.3	2.5	2.6
1980 CASE I (F.E.A.)	26.0	10.1	6.6	3.3	5.9
CASE I (Our Model)	20.0	13.0	1.4	3.4	2.3
CASE II (F.E.A.)	27.4	9.8	7.8	3.7	6.0
CASE II (Our Model)	20.3	12.7	2.0	3.3	2.3
CASE III (Our Model)	20.4	11.4	2.9	3.4	2.7
1985 CASE I (F.E.A.)	28.7	10.5	7.4	4.1	6.7
CASE I (Our Model)	22.3	14.1	1.1	4.4	2.7
CASE II (F.E.A.)	30.6	9.7	9.3	4.6	6.9
CASE II (Our Model)	22.6	13.7	2.0	4.2	2.6
CASE III (Our Model)	22.2	11.3	3.4	4.5	3.1

FIGURE 15

CASE I = $11/Bbl. CASE II = $7/Bbl. CASE III = No O.P.E.C.

*FEA results from tables AII-14, and AII-16, pps. 75 and 77, reference [5].

Analysis of the trends in future fuel consumption patterns derived from the two models for Cases I and II (using the same price scenarios) reveals four interesting divergences:

1. Our projected gas consumption increases by about 20% from 1972 to 1985 for the price scenarios used, but the F.E.A.'s gas consumption projections decrease for the same price scenarios.

2. Our projected oil consumption decreases by 1985 to about 50% of 1972 for $11 per barrel oil and remains essentially constant for $7 per barrel oil, but the F.E.A. projects a 30% increase for $11 per barrel and a 60% increase for $7 per barrel oil. (The major reason for this is our exclusion of feedstocks. More will be said of this shortly).

3. Our projected coal consumption decreases by about 25% by 1985 for the price scenarios used, while the F.E.A. projects a 50-60% increase in coal consumption by 1985. In addition, as the oil price decreases, the F.E.A. coal consumption increases, while our model demonstrates the opposite trend in behavior.

4. Where, by 1985, the F.E.A. model results in 25% and 33% increases in total industrial energy consumption for the $11 and $7 per barrel cases, respectively, our model results in 13% and 15% increases. (Again, part of the difference is due to feedstocks).

In fact, the only similarity in behavior is that both models project essentially the same patterns in electricity demand.

Unfortunately, the F.E.A. does not separately report their projection for petrochemical end-uses, making the forecasts <u>not</u> entirely comparable. An alternative is to separately add a projection for feedstock demands to our model results.

It has already been reported that raw material use comprised about 3.5 quadrillion BTU's of the F.E.A. 1972 consumption data, most of which (3.4 quads) is accounted for by oil. If we assume demand growth in this end use category will be 5% per year between 1972 and 1985, then the 1985 use of fuel for feedstocks would be about 6.6 quads (consisting of about 0.2 coal, 0.1 natural gas, and 6.3 oil)[19]. If we add these numbers to those derived from our model, the projected 1985 consumption numbers become:

	TOTAL	GAS	OIL	ELEC.	COAL
1985 CASE I (F.E.A.)	28.7	10.5	7.4	4.1	6.7
1985 CASE I (Our Model plus feedstocks)	28.9	14.2	7.4	4.4	2.9
1985 CASE II (F.E.A.)	30.6	9.7	9.3	4.6	6.9
1985 CASE II (Our Model plus feedstocks)	29.2	13.8	8.3	4.2	2.8
1985 CASE III (Our Model plus feedstocks)	28.8	11.4	9.7	4.5	3.5

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[19] The historical patterns of industrial raw material use of fuel have been:

1960 - 1.4 quadrillion BTU's
1968 - 2.2 quadrillion BTU's
1972 - 3.5 quadrillion BTU's

for a 1960-1972 growth rate of 7.9% per year.

We use a value of 5% for 1972-1985 to reflect the presence of some price response as well as to partially incorporate the decrease in economic activity of the past 18 months. In addition, this value makes the total demand projections of the two models comparable so that we can better view the differences in fuel substitution behavior.

Having done this, the large disparities in total energy demand and oil demand disappear leaving only the large and diverging trends in gas and coal demands.

The reasons underlying these differences, are attributable to the differences in estimated coefficients of the two models. The F.E.A. reports their estimated own-price and cross-price elasticities for the industrial sector on page 62 of Appendix A-II of the Project Independence Report.

The three major differences are:

1. The F.E.A. model has an own-price elasticity for natural gas of -1.5 vs. an estimated value of -0.8 in our model.

2. The F.E.A. model has an own-price elasticity for coal of -0.59 vs. an estimated value of -1.1 in our model.

3. The F.E.A. model exhibits a negative cross-elasticity between coal consumption and oil prices.

Because of these differences, the F.E.A. projects much less gas demand and much more coal demand than our model for the same price scenarios.

Finally, it is interesting that the "No O.P.E.C." case results in essentially the same total demand forecasts as the first two cases. The only significant difference appears in the configuration of fuels consumed. This is an illustration of the effects of the relatively low total demand elasticity and high substitution elasticities in this sector. The changed price configuration results in more oil, coal, and electricity demand, and less gas demand -- exacly as one would expect given the price assumptions depicted in Figure 14.

IV. CONCLUSIONS

It has been argued elsewhere that the F.E.A. has probably underestimated future gas and coal demand and over-estimated future oil demand[20]. For the industrial sector our results confirm that natural gas demand has been underestimated. Our results do not support the conclusion that oil demand has been over-estimated for this sector, mainly because of the predominance of growth in feed-stock uses, and rather than underestimating coal demand, our work suggests that coal demand has been overestimated by the F.E.A.

This has important implications for policy analysis and forecasting in the Project Independence context, but it does not invalidate the F.E.A.'s results with regard to future oil requirements. Our model confirms that alternative energy forms are highly substitutable in the industrial sector, that the fuel consumption patterns are highly dependent on the costs of competing fuels, and that geographic trends of industrial development may be highly dependent upon the availability of low cost energy resources. These are important concepts that need to be incorporated into the analysis of future energy policy alternatives.

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[20] See Ref [13], chapter 3.

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APPENDIX: DATA SOURCES AND DERIVATION

The data we have used is from many different sources. Unfortunately, the fuel consumption categories do not always cover exactly the same uses, but we've made every effort to reconcile differences across sources.

The price data (which is at the retail level) is in $/BTU: the consumption data is in BTU's; value added is in dollars, other variables are in similar singular units.

Natural Gas:

The industrial gas consumption data is the "total" category minus the "Electric utilities", "residential" and "commercial" categories in the U.S. Bureau of Mines' Minerals Yearbook as shown in the "value and consumption" table.

The gas price data is constructed by using the total consumption figures described above plus the electric utilities consumption, and dividing this into the total value of all this consumption. The electric utilities sector is necessarily used to construct a price because, until 1967, there is no value of consumption that does not include the electric utilities sector. Thus, an average price is constructed, though it does not exactly correspond to the fuel consumption which we are concerned with.

The gas figures are converted from million cubic feet units to BTU's by the Edison Electric Institute Statistical Yearbook gas conversion factors for electric utilities' fuel consumption.

Oil and Coal

Industrial oil consumption includes distillate and residual oil and non-heating kerosine in the "industrial", "oil company fuel", and "miscellaneous" categories, except for on-highway diesel oil in the miscellaneous category. All data are from the Mineral Industry Survey's "Shipments of Fuel Oil and Kerosine". Shortcomings of this data are that the industrial category does not consistently include or exclude industrial heating oil, and that even the Bureau of Mines itself is unable to describe what primarily is included in the miscellaneous category besides diesel oil.

Coal consumption data is from the Minerals Yearbook table "Distribution of Bituminous Coal and Lignite by Destination and Consumer Use", and is the sum of the "coke and gas plants" and the "all other" categories, which excludes retail sales and sales to electric utilities. This is the most indefinite of all the fuel consumption data categories; however, no better can be done on any scale, though it can reasonably be assumed that most industry does not buy its coal from retail outlets. The short-coming here is akin to that of oil -- the "all other" category will include relevant consumption, but it will certainly also include a lot of irrelevant consumption -- this is impossible to trace at the state level.

The oil consumption data is converted from barrels to BTU's as follows: residual = 6.287×10^6 BTU's/barrel; distillate = 5.825×10^6 BTU's/barrel; kerosine = 5.67×10^6 BTU's/barrel. These conversion figures come from the 1971 edition of the American Petroleum Institute Handbook. The coal consumption data is converted from tons to BTU's by the coal-consumed by electric-utilities conversion factors in the Edison Electric Institute's Statistical Yearbook.

Both the coal and oil price series were created (since no by-state industrial price series were available) by using the 1962 Census of Manufacturers prices for these fuels in 1962. The coal price is then extended through 1972 by means of the derived yearly percentage increases in the electric utilities prices of the fuels from the Edison Electric Institute's Statistical Yearbook. The oil price is extended by the same method, according to the # 2 fuel oil prices from the American Gas Association's "Gas Househeating Survey" instead.

Electricity

Industrial electricity consumption and price is from the Statistical Yearbook's "Sales and Revenues" categories under "Large Light and Power", whose drawback is the possible inclusion of large commercial firms and other irrelevant large firms and the possible exclusion of small industrial firms. The average price of electricity is merely Revenues divided by Sales, as with natural gas. Here, especially, it would be good to have marginal prices, but the only marginal electricity prices available are from the "Typical Electric Bills" publications, and then by-state only for the residential-commercial sector. The electricity figures, in Kwh, are converted to BTU's by 3412.8 BTU's/Kwh.

Average Price Variables for State Allocation and Fuel-Split Equations

The average prices used in the state allocation equation are created by calculating a weighted average of individual state fuel prices, the weights being state fuel market shares.

The average prices in the total-demand equation are created by computing a weighted average of the average prices in the state allocation equation, the weights being each state's share of total U.S. industrial energy consumption.

Miscellaneous

The population data is from the Bureau of the Census.

The value-added figures and fractions (derived from twenty S.I.C. code values in each state) used interactively with other variables come from the Census of Manufacturers and the Annual Survey of Manufacturers.

The dollar deflator is the wholesale price index for non-farm industrial commodities in constant 1957 dollars.

We would have liked very much to have explicit data on the agricultural sector, e.g., value-added, which is, of course, unaccountable. In addition, gas, oil, and electricity used non-residentially in the agricultural sector are included in such places as the "residential" as well as in the "other" categories for gas, in the "miscellaneous" or "heating" categories for oil, and in the "residential" or "small light and power" categories for electricity. In sum, some discrepancies of fit may be due to this inadequacy and inconsistency.