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The Employment Impact of Changing Energy Prices

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Introduction

The purpose of this paper is to develop a model that relates changes in employment to changes in energy prices. Although the employment effects of various energy price and policy scenarios have been previously studied, most models are of limited usefulness because they ignore either the substitution of other inputs for energy as its relative price rises, or the impact of higher energy prices on the level of output and employment. Moreover, previous studies have not incorporated data from the recent period of rapidly rising energy prices, which provides a good basis for evaluating the potential impact of future price changes. In the manufacturing sector, for example, the price per 1000 KWH equivalent for all fuels and purchased electricity increased by 140% between 1971 and 1975. The increase varied among states from 57% in North Dakota to 239% in Texas, and among industries from 120.1% in fabricated metals to 175.8% in paper products.[1]

The paper develops a model that estimates the total employment effect of changing energy prices as the sum of the substitution and scale (or output) effects. The model is estimated cross-sectionally with state data for five energy intensive and five non-energy intensive manufacturing industries. If the model produces reliable estimates, the results can be used to predict changes in State employment by industry that may result from energy price changes which are induced by either market forces or national energy policy. Unfortunately, the estimated effects vary substantially among the industries, and are not often significantly different from zero.

Previous studies of the employment effects of changing energy prices and their limitations are discussed briefly in the following section. The models to be estimated are developed in the third section. The data, estimation procedures, and findings are presented in the fourth section. The last section discusses the results and their implications.

Models of Energy-Price Employment Effects

There are three general approaches that have been used to estimate the employment effects of energy price changes: large scale macroeconomic models of the economy;[2] estimation of the elasticities of factor substitution and factor demand in a production function

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[1] 1972 Census of Manufactures, "Fuels and Electric Energy Consumed," Supplement MC 72 (SR)-6S and Annual Survey of Manufactures 1975, "Fuels and Electric Energy Consumed," M 75 (AS)-4.

[2] For example, the Wharton Econometric Forecasting Associates energy model, The Data Resources Transactions Model and the B.L.S. economic growth model.

framework;[3] and regional growth models.[4] Most large scale macro-models (e.g. the Wharton and D.R.I. models) produce employment estimates as a by-product of output forecasts. A review of these models and their capability for estimating employment effects is beyond the scope of this paper.[5] These models are based on input-output tables whose coefficients are invariant with respect to energy prices. Thus these models capture only the effects of changes in the composition of final demand, and do not reflect the substitution among factor inputs that may result from changing relative factor prices.[6]

A macro-model that estimates sectoral and occupational employment effects has been developed by Early and Mohtadi.[7] They used the B.L.S. input-output model, driven by a macroeconometric forecasting model, to obtain employment forecasts for 129 sectors and 470 occupations in 1985. These estimates are aggregated to produce employment estimates for ten major sectors and nine occupational categories. The most relevant finding is that manufacturing employment declines by about 1% if the price of imported crude oil rises to $16 per barrel (compared to a reference price of $13 per barrel).

The methodology of the Early-Mohtadi study has serious limitations, which the authors acknowledge. Among the more important are outdated industry energy consumption data, and the absence of substitution among inputs as energy price change.

The production function approach to estimating the employment impact of energy price changes has been taken by Berndt-Wood, Griffin-Gregory and Hudson-Jorgenson. Both Berndt-Wood and Hudson-Jorgenson estimate four factor translog cost functions for U.S. manufacturing for the 1947–1971 period. Both studies find labor and energy to be substitutes, implying that a rise in the price of energy relative to wages will increase employment. The estimated cross price elasticities (of labor with respect to the price of energy) are .03 for Berndt-Wood and .04 for Hudson-Jorgenson.

The Griffin-Gregory study employs the same four factor translog cost function approach but applies it to the manufacturing sectors of nine industrialized nations. They too find that labor and energy are substitutes, estimating the cross price elasticity to be .08 to .15. It is interesting that the elasticity of employment with respect to energy prices calculated by Early-Mohtadi is −.03 to −.04. The difference in signs is significant in that it underscores the limitations of both approaches. Since the translog cost function method holds output constant, the factor demand elasticities reflect only the substitution effect of a price change, which is positive in the case of employment and energy prices. The input-output method allows no substitutions and thus measures only the negative output effect of higher energy prices.

Regional employment effects of energy price changes have been studied by Huntington and Smith. They estimated the effect of energy prices on the growth of employment, capital and output in the manufacturing sector. They argue that output growth depends on the growth of the inputs, which is a function of factor payments. Higher energy prices reduce factor payments and thus the growth of the factors and output. They find that employment and capital growth are inversely related to energy prices across States between 1963 and 1972. Since the variables used in the Huntington-Smith model were composites, direct elasticity estimates cannot be derived from their parameter estimates.

There are several shortcomings to the Huntington-Smith growth model. First, it estimates long-run adjustments, since factor growth is related to factor price levels rather than price changes. It would therefore not apply to time periods in which their are substantial changes in the variance of energy prices across states. Second, Huntington-Smith treat the manufacturing sector as an aggregate. Since energy intensity varies widely across the industries in the manufacturing sector,[8] the response of these industries to energy price differences will also vary. It should be noted that the production function studies cited above also treat the manufacturing sector as an aggregate. This choice of level of aggregation is probably due to the "data intensiveness" of the translog cost function approach. The disaggregated approach adopted here has the advantage of permitting the elasticity of employment with respect to energy prices to vary across industries.

A MODEL OF EMPLOYMENT AND ENERGY PRICES

In this section we develop a model which avoids some of the major limitations of previous research. The four most serious problems are: (1) the failure of any of the previous studies to capture both the substitution and scale effects of an energy price change; (2) the aggregation bias that results from using the manufacturing sector as the unit of observation; (3) the absence of employment impact estimates that are specific to both industry and state; and (4) the absence of estimates that refer to a period of substantial energy price changes. These problems are overcome by developing a model that follows closely the theory of factor demand and applying that model to ten two-digit manufacturing industries using data for the 1971 to 1975 period.

According to theory, the short-run profit maximizing behavior by competitive firms can be represented as a two stage process: the optimal quantities of factor inputs are chosen, given factor prices; the optimal level of output is then chosen, subject to the firm's cost function and the market determined product price. Therefore, the total impact of a change in factor price on the quantity of a factor demanded consists of a substitution effect and a scale or output effect.[9] This holds for own price changes and for changes in the price of other factors. Moreover, if output is a function of more than two inputs, the cross price elasticity of demand may be either positive or negative. In the case of substitutes, which the evidence suggests energy and labor are, the direction of change depends on the elasticity of substitution between the two factors and the elasticity of commodity demand. Specifically,[10]

$$\partial X_j/\partial P_k \gtreqless 0 \quad \text{as} \quad \sigma_{jk} \gtreqless (\eta - 1)/2$$

where $\partial X_j/\partial P_k$ is the change in the quantity of input j with respect to the price of input k,

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[3] See E. R. Berndt and D. O. Wood, "Technology, Prices, and the Derived Demand for Energy," *Review of Economics and Statistics*, August, 1975; J. M. Griffin and P. R. Gregory, "An Intercountry Model of Energy Substitution Response," *American Economic Review*, December, 1976; and E. A. Hudson and D. W. Jorgenson, "U.S. Energy Policy and Economic Growth, 1975–2000," *Bell Journal of Economics*, Autumn, 1974.

[4] See H. G. Huntington and J. R. Kahn, "Regional Industrial Growth and Energy Prices," mimeo, July 1977 and H. G. Huntington and D. M. Smith, "Energy Prices, Factor Reallocation and Regional Growth," Federal Energy Administration Working Paper 76-WPA-53, January 1977.

[5] For an in depth review of these models see A. H. Eckstein and D. Heien, "A Review of Energy Models With Particular Reference to Employment and Manpower Analysis," Employment and Training Administration, D.O.L., March, 1978.

[6] Some input-output models do allow coefficients to be energy price sensitive e.g. the complete Hudson-Jorgenson model.

[7] R. F. Early and M. M. Mohtadi, "Alternative Energy Futures and the Structure of Employment in the U.S. Economy," F.E.A. Working Paper, September 1976.

[8] The ratio of energy cost to value added varied in 1971 from .008 in the tobacco industry to .113 in the petroleum and coal products industry. See R. Halvorsen, "Energy Substitution in U.S. Manufacturing," *Review of Economics and Statistics*, November 1977.

[9] See C. E. Ferguson, *The Neoclassical Theory of Production and Distribution*, Cambridge, 1969, especially pp. 141–153.

[10] This expression applies to the case of a linear homogeneous production function. For more general production functions the expression is more complex but yields the same results. See Ferguson, p. 152.

σ_{jk} is the elasticity of substitution between j and k, and η is the elasticity of commodity demand. Thus the greater the substitution elasticity and the smaller the commodity demand elasticity the greater the likelihood that of a positive total effect, and vice-versa.

This analysis leads to two conclusions. First, determining that the elasticity of substitution between inputs is positive is not sufficient to conclude that a rise in the price of one, say energy, will increase the amount demanded of the other, say labor. Second, since commodity demand elasticities vary widely among the industries of the manufacturing sector it is misleading to lump them together. It may be that rising energy prices will increase employment in some industries and decrease it in others.

The model adopted here assumes a three factor production function, which can be written in general form as $Q = f(L, K, E)$ where Q is net output, L is labor, K is capital and E is energy.[11] Assuming that firms maximize profits and that factor prices are exogenously determined, the function f can be inverted to yield a labor demand function

$$L = g(Q, W, P_K, P_E) \qquad (1)$$

where W is the wage rate, P_K the price of capital and P_E the price of energy. From the preceding discussion it should be clear that regression estimates of the parameters of (1) will not yield the desired total impact of an energy price change on employment. The estimate of $g_4(L/P_E)$ is solely the substitution effect since output (Q) is held constant. We now consider two approaches to estimating the total impact of an energy price change on employment.

Since the difficulty with (1) is that it holds Q constant, a naive approach is to drop Q from the equation. With this specification g_4 may be interpreted as the total effect of an energy price change on employment. However, the estimated coefficient will clearly include the effects of any other factors influencing Q that are not in the model, and thus will likely overstate the true effect of the energy price change. Moreover, separate estimates of the substitution and output effects will not be possible, making comparisons with other research difficult.

A second approach recognizes that the substitution and output effects occur simultaneously. What is needed is a model that relates factor price changes to output. Recalling that our observations are states we can borrow from the regional growth literature[12]

$$Q = h(W, P_K, P_E, Z) \qquad (2)$$

where Z is a vector of factors in a state that may effect output. Equation (2) argues that output across states depends on input prices and other cost related factors. Thus it is purely a supply side explanation of the relative output of states. For the manufacturing industries that sell in national markets this is reasonable.[13] We must assume, however, that over the period in question (1971–1975) there were no changes in transportation costs (or other costs not included in the model) or product demand that changed the net advantage of location in one state vis-a-vis any other state.

The total energy price effect on employment can be expressed as $\partial L/\partial P_E + \partial Q/\partial P_E \cdot \partial L/\partial Q$ or $dL/dP_E = g_4 + h_3 \cdot g_1$ where g_4 is the substitution effect and $h_3 \cdot g_1$ is the output effect. Although this approach is analytically equivalent to the naive one posited above, it is preferable because each effect is separately estimable.

The equations actually estimated differ in several respects from (1) and (2). First, output and employment are defined as the percentage change from 1971 to 1975, and P_E and W are the absolute change during the period.[14] Since the model relates changes in employment to changes in the independent variables, it assumes that firms were employing the optimal amount of labor in 1971. Although we do not have direct evidence on this point, it seems likely that relative factor prices had not changed rapidly prior to 1971. Therefore, the assumption of optimal input proportions probably does not do much harm to reality.[15]

A similar argument can be made regarding the variance across states of the cost of capital, P_K, over the 1971 to 1975 period. We assume that there is no change in that variance and, therefore, that P_K can be omitted from (1) and (2). This assumption is necessary because capital cost data by state and industry are not available. Although interest rates rose between 1971 and 1975, capital markets are probably efficient enough to eliminate interstate differences for firms in the same industries.[16] Omission of P_K is likely to result in biased estimates of the remaining parameters. However, the actual effect is probably small because capital spending is not too sensitive to interest rates. Other factors, such as those included in Z, may have a greater impact on the expected rate of return to new investments and thus on capital spending.

Three variables are included in Z: T, the percentage of state income that is collected as state taxes; U, a proxy for union strength in the state; and NG, the amount of natural gas produced in the state.[17] The variable NG was included to test the hypothesis that firms may move to, and thus output will grow more rapidly in, states with certain natural gas supplies. A feature of the current energy regulatory system is the higher price of natural gas sold within producing states. Firms may be willing to trade higher prices for supply certainty, particularly if energy costs are not a large percentage of total costs.

Finally, we add stochastic disturbances to (1) and (2). Since changes in output and employment are closely related, it is likely that these disturbances, which reflect the influence of various factors which cannot be measured and controlled for, will also be correlated. Thus although (1) and (2) are not a true simultaneous equations system, a simultaneous estimation technique is called for. The equations estimated are:

$$L^* = f(Q^*, W^*, P_E^*, \lambda_1) \qquad (1')$$

$$Q^* = g(W^*, P_E^*, U, T, NG, \lambda_2) \qquad (2')$$

where
L^* = % change in production worker manhours
Q^* = % change in value added
P_E^* = change in the price per Kilowatt-hour equivalent of fuels plus electric energy consumed
W^* = change in the average hourly wage of production workers
U = a proxy for union strength; = 1 if the state had a right to work law and = 0 otherwise

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[11] If Q is net output or value added then energy should not be included as an input because energy purchases are netted out when calculating value added. This formulation assumes that firms pass through 100% of any energy cost increases. Below we report on an alternate specification that measured Q net of energy costs.

[12] In particular see Huntington and Kahn, "Regional Industrial Growth and Energy Prices."

[13] Some manufacturing industries, such as stone, clay and glass—which contains the cement industry, sell most of their output locally.

[14] Firms' costs are changed by the quantity of an input used times the change in price. Thus absolute rather than percentage input price changes are appropriate measures of the impact on costs. Below we discuss the alternative of specifying all the variables as percentage changes from 1971 to 1975.

[15] The alternative of using price levels as independent variables presents the additional problem of choosing in which year to measure prices.

[16] The average yield on corporate industrial bonds was 7.57% in 1971, 9.25% in 1975. See the *Federal Reserve Bulletin*, February 1976.

[17] A better measure of union strength might be percent of workers unionized. Unfortunately, this measure is not available by state and industry.

T = state tax revenue from all sources as a percentage of state income
NG = natural gas production, billions of cubic feet
λ_1, λ_2 = stochastic disturbances assumed to be uncorrelated with the independent variables in their respective equations, but not with each other.

Using subscripts to denote the number of the argument in each equation the expected signs of the coefficients to be estimated are

$$f_1, f_3, g_3, g_5 > 0$$

$$f_2, g_1, g_2, g_4 < 0$$

It can be argued that P_E^* as defined is too crude a measure of the price of energy. Although it is a weighted average of the prices of all energy sources, across states the same industry may use different proportions of each source. It might be more appropriate therefore to use the individual prices of each type of energy. Unfortunately, this approach precludes the possibility of intersource substitution, which Halvorsen has been found to be substantial.[18] We thus rely on the weighted average price of energy types as the best available measure of energy prices facing manufacturing firms in each state.

The Empirical Model

This section describes the data used and discusses their limitations. The equations estimated are presented, and alternative specifications which were tried but not reported here are noted.

The major sources of data for this study are the 1975 Annual Survey of Manufactures and the 1972 Census of Manufactures.[19] These sources provided 1975 and 1971 data on production worker manhours and wages, value added, and fuels and electric energy consumed. State data are used as observations for each two-digit industry. Above I argued that disaggregation of the manufacturing sector was necessary because of the wide variations across industries in amount and type of energy used, and because it should not be assumed that the employment change in response to an energy price change will be the same in all industries. The production functions may differ, implying a different elasticity of substitution between labor and energy. Furthermore, product demand elasticities may also differ so that the total effect of an energy price change would be different even if the substitution elasticities were the same.

Not surprisingly, disaggregation creates a different set of problems. First, even at the two digit level not every state has activity in all of the ten industries selected. The number of observations thus varies across industries, and the low energy intensity industries were chosen because they had enough observations to provide adequate degrees of freedom.

The quality of the data, too, suffers from disaggregation by state and industry. The standard errors of estimate of the data become fairly large in those states where there are only a few establishments, or small establishments, in an industry. The question of data reliability is underscored by the fact that in some states the Census Bureau reported data for an industry in only one of the two years used here. Of course these observations could not be included in the data set.

Despite the data problems associated with disaggregation to the two-digit S.I.C. level, I believe the approach has advantages. There are very substantial differences in energy usage and costs among the ten two-digit manufacturing industries selected here. Energy usage (measured as KWH per constant dollar of value added) and energy prices in 1971 and 1975, and the precentage change in each over the period, are shown in Table 1. The energy intensive industries use about 7 times as much energy per dollar of value added on average as the non-intensive industries. It is interesting to note that the low energy use industries pay higher unit prices, but that the percentage price increases from 1971 to 1975 were similar for both groups. The percentage reduction in energy usage was also similar. It should be noted that, except for S.I.C. 26, which had the largest price increase and usage decrease, energy price changes and usage changes are not negatively correlated. Apparently technology or other factors limit the extent of substitutability in some industries.

A crucial and controversial aspect of this study is the choice of time period. It was argued above that since previous studies were limited to data up to 1971 they missed the recent period of large energy price changes. Therefore, they were not appropriate for estimating the employment impact of substantial energy price changes. However, the 1971 to 1975 period is one of substantial inflation and the sharpest recession in the post World War II era. Of course, the energy price changes induced by the growing imbalance between world demand and supply, and especially the crude oil embargo of 1973–74, were major factors in both the recession and the high rate of inflation. Nonetheless, one must be concerned about the extent to which these findings can be generalized to another period in time in which energy prices increase significantly and relatively rapidly. Since previous work precedes the 1971–1975 period, this study should be viewed as supplementing rather than supplanting the findings of other researchers.

The estimation procedure employed began with the naive model posited above. That model was equation (1) with Q^* omitted. Rather than estimate that model, which is deficient because other factors that may influence Q^* and thus L^* are not included, (2′) was substituted into (1) yielding

$$L^* = h(W^*, P_E^*, U, T, NG, \lambda_3) \tag{3}$$

The ordinary least squares regression estimates of the paramters of (3) are presented in Table 2.

The coefficient of the key variable, P_E^*, is negative in eight of ten industries, and significantly different from zero in four of the eight

TABLE 1 Energy Usage and Energy Cost by Industry, 1971 and 1975

		KWH/VA[1]			*Cost/1000 KWH*		
S.I.C.	*Industry*	*1971*	*1975*	*% Δ*	*1971*	*1975*	*% Δ*
20	Food	9.83	7.42	−24.5	$3.02	$ 7.42	145.7
26	Paper	40.38	25.72	−36.3	2.40	6.62	175.8
28	Chemicals	30.76	26.49	−13.9	2.70	6.32	134.1
32	Stone, Clay, Glass	39.17	30.72	−21.6	2.23	5.61	151.6
33	Primary Metals	40.10	27.22	−32.1	3.58	7.91	120.9
Av'g	High-Use Industries	28.55	21.88	−23.4	2.95	6.94	135.3
30	Rubber, Plastics	8.63	7.33	−15.1	4.36	10.73	146.1
34	Fabricated Metals	5.23	4.67	−21.7	4.42	9.73	120.1
35	Machinery, Non-electric	4.00	2.65	−33.7	4.79	10.88	127.1
36	Electrical equipment	3.57	2.70	−24.4	4.69	10.77	129.6
37	Transportation equipment	4.42	3.19	−27.8	4.38	9.98	127.9
Av'g	Low-Use Industries	4.63	3.53	−23.8	4.53	10.37	128.9

[1] 1975 Value Added was deflated to reflect the increase in prices between 1971 and 1975.
Sources: 1972 Census of Manufactures, 1975 Annual Survey of Manufactures.

[18] R. Halvorsen, "Energy Substitution in U.S. Manufacturing," *Review of Economics and Statistics,* November 1977, 381–388.

[19] See footnote 1 for exact references. The state tax variable was constructed from Tables 428 and 629 of Statistical Abstracts, 1974. The natural gas production data were obtained from *Oil in Your State,* Independent Petroleum Producers Association.

TABLE 2 Regression Estimates of Percentage Change in Employment, 1971–1975

S.I.C.	*N*	*Constant*	W^*	P_E^*	U	T	NG	R^2
20	42	.21	−.189 (.030)[a]	−.027 (.007)[a]	.042 (.027)	.005 (.006)	−.01 (.02)	.61
26	31	.36	−.210 (.051)[a]	−.022 (.015)	.009 (.034)	−.013 (.007)[c]	.001 (.02)	.44
28	36	.84	−.483 (.118)[a]	−.053 (.026)[b]	−.019 (.07)	−.003 (.005)	.032 (.082)	.43
32	34	.11	−.082 (.05)	−.030 (.017)[c]	.009 (.05)	.019 (.016)	.041 (.03)	.18
33	29	.16	−.119 (.049)[b]	−.038 (.01)[a]	−.029 (.047)	.011 (.013)	.043 (.029)	.47
30	24	.27	−.153 (.109)	−.007 (.013)	.042 (.063)	.015 (.017)	.035 (.062)	.25
34	34	−.31	.154 (.178)	.014 (.012)	.052 (.075)	−.002 (.023)	.015 (.044)	.74
35	33	.16	−.154 (.106)	−.025 (.017)	.155 (.076)[b]	.016 (.021)	.066 (.051)	.36
36	32	−.18	.065 (.027)[b]	−.005 (.013)	.034 (.053)	.001 (.003)	.02 (.033)	.19
37	26	−.05	−.096 (.133)	.006 (.014)	.057 (.098)	.006 (.02)	.014 (.037)	.15

a = significant at the .01 level, two-tailed test.
b = significant at the .05 level, two-tailed test.
c = significant at the .10 level, two-tailed test.

TABLE 3 Regression Estimates of Percent Change in Value Added, 1971–1975

S.I.C.	*Constant*	W^*	P_E^*	U	T	NG	R^2
20	.24	.142 (.045)[a]	−.006 (.01)	.155 (.042)[a]	−.005 (.009)	−.013 (.03)	.47
26	.93	−.194 (.103)[c]	−.046 (.031)	.112 (.068)	−.017 (.015)	.034 (.041)	.35
28	.90	.188 (.274)	−.156 (.06)[b]	−.023 (.164)	−.007 (.011)	.047 (.192)	.22
32	.13	.018 (.141)	−.050 (.047)	.102 (.141)	.023 (.045)	−.018 (.085)	.75
33	.42	−.109 (.146)	−.065 (.030)[b]	.102 (.14)	.036 (.04)	.007 (.085)	.22
30	.04	.318 (.161)[c]	.035 (.019)[c]	.062 (.092)	−.029 (.025)	.019 (.036)	.25
34	−.15	.57 (.251)[b]	.018 (.016)	.021 (.106)	−.025 (.032)	.075 (.062)	.21
35	.21	.059 (.152)	−.007 (.025)	.281 (.109)[b]	.008 (.03)	.139 (.074)[c]	.35
36	.02	.051 (.049)	−.003 (.023)	.140 (.095)	.011 (.006)[c]	−.026 (.06)	.16
37	.14	.036 (.251)	−.016 (.027)	−.004 (.184)	.009 (.039)	.111 (.07)	.13

a = significant at the .01 level, two-tailed test.
b = significant at the .05 level, two-tailed test.
c = significant at the .10 level, two-tailed test.

(food; chemicals; stone, clay and glass; and primary metals). For those four industries a one dollar per KWH increase in energy prices appears to be associated with a 3% to 5% decrease in employment. In terms of the theory of factor demand, the results imply that the scale effect is larger than the substitution effect. The coefficients are positive in the fabricated metals and transportation equipment industries, but are not significantly different from zero.

The variables U, T, and NG appear to have no effect on L^*. W^*, as expected, generally has negative coefficients, in four cases statistically significant. In the fabricated metals and electric equipment industries the coefficients are positive. This anomaly may be due to an identification problem, i.e. W^* may be endogenous to a larger system of equations which has not been specified or estimated.

Estimates of the two equation model composed of (1′) and (2′) are presented in Tables 3 and 4. Two stage least squares was applied to the system so that (1′) becomes

$$L^* = f(\hat{Q}^*, W^*, P^*_E, \lambda_1) \tag{4}$$

where $\hat{Q}^*$ is the predicted value of Q^* obtained from the first stage OLS estimate of (2′).

The estimates in Table 3 indicate that energy price increases tend to reduce the growth of value added across states. However, the results for W^* are mixed, perhaps because of the simultaneity problem referred to above.[20] No consistent relationship between U, T and NG and the growth of value added is indicated in Table 3. The scale effect of a one dollar per KWH increase in energy prices is to reduce Q^* by as much as 15% in the chemicals industry, but by less than 1% in some other industries.

The 2SLS estimates of (1′) are presented in Table 4. Recall from the preceding section that the sign of the coefficient of P^*_E is expected to be positive if, as other studies have found, energy and labor are substitutes. In fact, the results show that the coefficients of P^*_E are mainly negative. In the three cases in which they are positive (SIC's 28, 34, 37), they are not significantly different from zero. In three industries with negative coefficients (SIC's 20, 30, 35), the results are statistically significant. The implication of these findings is that during the 1971–1975 period, energy and labor were complimentary inputs rather than substitutes. The coefficients of W^* and $\hat{Q}^*$ are consistently negative and positive, respectively, as expected.

The anomalous results for P^*_E will be discussed further in the following section. First, however, I wish to make mention of alternative specifications of the model which were estimated. It should be noted that none

TABLE 4 2SLS Regression Estimates of Percentage Change in Employment, 1971–1975

S.I.C.	*Constant*	W^*	P_E^*	$\hat{Q}^*$
20	.23	−.221 (.039)[a]	−.025 (.007)[a]	.216 (.169)
26	−.03	−.134 (.044)[a]	−.009 (.015)	.286 (.151)[c]
28	.44	−.565 (.198)[a]	.016 (.119)	.446 (.733)
32	.05	−.086 (.048)[c]	−.021 (.026)	.117 (.423)
33	.10	−.089 (.054)	−.025 (.019)	.162 (.274)
30	.27	−.34 (.088)[a]	−.027 (.009)[a]	.585 (.227)[b]
34	−.16	−.039 (.175)	.01 (.008)	.292 (.276)
35	.18	−.185 (.063)[a]	−.019 (.011)[c]	.490 (.118)[a]
36	−.16	.058 (.024)[b]	−.007 (.01)	.079 (.233)
37	.06	−.159 (.07)[b]	.009 (.011)	.157 (.253)

a = significant at the .01 level, two-tailed test.
b = significant at the .05 level, two-tailed test.
c = significant at the .10 level, two-tailed test.

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[20] States with large increases in Q^* are likely to have large increases in the demand for labor, which tends to bid wages up.

of the alternatives produced results which were in any sense "better" than those presented in Tables 2, 3 and 4, and the results were frequently both less consistent and less reliable.

One potentially serious problem with our choice of value added as an output measure, is that this measure is net of all purchases of goods and services from other firms, including fuels and electric energy. Therefore, if gross output remained the same but energy expenditures increased because of the rise in their price, value added would decline. By ignoring this problem I have implicitly assumed that firms pass through 100% of all such cost increases i.e. that value added is not affected. This assumption was tested by substituting an adjusted measure of value added which subtracted out the change in energy expenditures. This is equivalent to assuming that firms pass on none of the higher costs. The results of this experiment were not significantly different from the original specification. Since these two cases represent the extremes of 100% and 0% cost pass through of energy cost changes, I conclude that the model is not sensitive to this problem.[21]

I was also concerned that the measure of labor demand, manhours, was too sensitive to various short-run factors. Therefore, the equations were estimated using the percentage change in employment for L^*. The results were similar to those presented here. I also experimented with different measures of factor price changes. W^* and P_E^* were expressed in percentage terms, with no significant effect on the results. Using the mean wage and energy price as explanatory variables also did not affect the results.

Some researchers have suggested other variables in addition to U and T which might affect the growth of output among the states.[22] No significant relationship was found between either Q^* or L^* and the mean January temperature in the state, the presence of either a state loan program or special tax concessions for industry.

Remarks

The most interesting and surprising finding of the study is the negative relationship between employment change and energy price change holding output constant. To facilitate comparison between the single equation and two equation approaches used in the preceding section, Table 5 was prepared. Table 5 shows for the two equation model the scale, substitution and total employment effects of a one dollar increase per KWH in the price of energy, and the corresponding total effect from the one equation model. Comparisons of the third and fourth columns of the table reveals that the total employment effect estimates of the two models are quite similar, as expected.

The similarity of estimated total effects does not diminish the value of the two equation approach. To the contrary, with the single equation estimates alone we would conclude that in most manufacturing industries a negative scale effect outweighed a positive substitution effect. The two equation model, by providing separate estimates of the scale and substitution effects, establishes that a different response appears to have occurred. In most of the manufacturing industries higher energy prices reduced employment, *ceteris paribus*. Only the chemicals industry (SIC 28) follows the expected pattern of positive substitution effect and negative scale effect.

The problem now is to provide an economically plausible explanation of the apparent complementarity between energy and labor, in light of previous findings of substitutability. I believe that there is such an explanation, and it is based on the shortness of the time period studied, the rapidity of the energy price rise, and the complementarity of energy and capital.

The unique problem faced by firms in the 1971–1975 period was adjusting to a large and rapid energy price increase. It is also important that although energy prices (especially crude oil) began rising prior to 1973, the biggest increases came late in the period, following the O.P.E.C. embargo. In the short-run most firms can reduce energy use in two ways: by reducing capital usage and thus output or by housekeeping measures such as lowering thermostats etc. In the longer-run, energy saving capital can replace older, less energy-efficient capital, but there is little opportunity for this in the short-run. If we assume that most energy use is tied closely to the level of output (also the case for raw materials), the only other variable factor of production is labor. I believe that the results presented here suggest that, in the absence of other short-run alternatives, many firms responded to the squeeze on profits caused by higher energy prices by eliminating marginal workers. Since 1974 was a recession year, and 1975 only the beginning of the upswing, many firms could accomplish this by simply slowing down the rehiring of previously laid-off workers.

TABLE 5 Total Percentage Change in Employment Induced by $1.00 per KWH Increase in Energy Price

	Two Equation Model			*Single Equation Model*
S.I.C.	*Scale*[a]	*Substitution*	*Total*	*Total*
20	−0.1%	−2.5%	−2.6%	−2.7%
26	−1.3	−0.9	−2.2	−2.2
28	−7.0	1.6	−5.4	−5.3
32	−0.6	−2.1	−2.7	−3.0
33	−1.1	−2.5	−3.6	−3.8
30	2.0	−2.5	−0.5	−0.7
34	0.5	1.0	1.5	1.4
35	−0.3	−1.9	−2.2	−2.5
36	0.0	−0.7	−0.7	−0.5
37	−0.3	−0.9	0.6	0.6

[a] The scale effect is computed as the product of the coefficient of P_E^* from Table 3 and the coefficient of $\hat{Q}^*$ from Table 4. See text for further explanation.

Of course it is true that at the beginning of expansions output rises more rapidly than employment and labor productivity increases. However, this is not sufficient explanation for our finding that employment growth was negatively related to energy price changes, holding output constant. My explanation is a variant of the "shock effect" theory. In the short-run firms had no other way to hold down costs—and those that suffered the largest energy price increases cut employment the most.

At the outset the paper held out the hope that industry-specific employment impact estimates could be used to project the increase in employment by state that would result from higher future energy prices. That hope was based on the expectation that the total employment effect would be positive in some industries, as found by Berndt-Wood, for example. Although that is the case in two industries, SIC's 34 and 36, those estimates are based on coefficients that are not different from zero at any reasonable level of statistical significance.

Perhaps the major lessons learned from this paper are first, that the short-run behavior of firms during periods of rapid factor price changes is likely to be quite different from what might be expected in the longer-run. This underscores the limitations of models estimated with data covering periods of relatively moderate price changes. In addition, the limitations of models that consider only the substitution or the scale effects of energy price changes were demonstrated. Hopefully, future research will apply comprehensive models to even more recent data.

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[21] It is possible that some intermediate case will produce different results. It was not possible, however, to test all such possibilities.

[22] See Huntington and Kahn and D. A. Hellman *et al*, *State Financial Incentives to Industry*, Lexington, 1976.

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