Input prices and cost inflation in three manufacturing industries

The transmission of inflation varies among industries, depending most heavily on differences in input cost changes; factor substitution plays a minor role

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Over the past two decades, U.S. industries have exhibited marked changes in their use of primary and secondary resources. Such changes have been due, at least in part, to the volatility of resource markets. For example, the rapidly rising energy prices of the 1970's led many firms to substitute away from energy and toward relatively less expensive inputs such as capital or labor. The ease with which producers are able to make these substitutions partly determines output price increases in their respective industries. Such price increases, in turn, affect factor substitution at later stages of processing, product substitution in consumption, and the general rate of inflation in the economy.

In this article, we analyze in detail the input-to-product inflation link in three key manufacturing industries: autos (Standard Industrial Classification 371), steel (SIC 331), and plastics (SIC 282).[1] These industries, particularly autos and steel, have undergone dramatic changes during the past 15 years and have been the subject of much recent research. Yet, relatively little attention has been given to the transmission of inflation between resource and product markets in the industries. Our study attempts to partially fill this gap with empirical evidence that quantifies the nature of this transmission.

The framework is a model of industrial input demand, adopted from the substantial literature on the study of industrial production.[2] Each industry is assumed to operate with a production function that incorporates four major factor inputs: capital (K), labor (L), energy (E), and materials (M). The industry combines these factors in the least costly way to produce a specified level of output. In this case, each industry is assumed to have a well-defined cost function that relates total production costs to the level of output and the prices of the inputs. The demand for each input can then be determined from the cost function.

In the model just described, the cost per unit of production (average cost) is a function of the four input prices and, in a competitive market, is equal to the output price. If the product market is not competitive, the relationship between input and output prices will be more complicated. We characterize our analysis as an investigation of the effects on "average cost" of changing input prices. The precise manner in which this effect occurs will depend upon the specific technology and implied factor substitutability that underlie the production process. The narrower the range of substitution possibilities, the greater is the transmission of input-to-cost inflation because of the limited ability of the industry to substitute away from costly inputs. We illustrate the importance of this issue by simulating average cost inflation in each industry under three alternative assumptions concerning factor substitutability.

Naturally, for any given production technology, the effect on average costs of changing input prices will also depend upon the time paths of input prices. We explore this issue by computing for each industry aggregate input price in-

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dexes that correspond to alternative scenarios for input price changes.

The first section of this analysis describes the data pertaining to the three industries and provides summary trends for key variables. The next section outlines the input-to-cost relationship that forms the basis for our simulations. The final section presents empirical results that bear on the substitutability of the four factors in each industry and illustrate the sensitivity of average cost inflation to different factor substitution possibilities and alternative input price scenarios.[3]

Trends in prices and quantities

The data for our analysis are annual price and quantity indexes (1972 = 1) represented, respectively, by P_K, P_L, P_E, P_M, and Q_K, Q_L, Q_E, and Q_M. (A full description of the underlying data and index number construction is available from the authors upon request.) P_K is an index of the rental price for the services of three major capital assets: producers' durable equipment, nonresidential structures, and inventories,[4] and Q_K is a quantity index of constant-dollar stock estimates for each of the three assets. P_L is an index of average hourly compensation for production and nonproduction workers in each industry, while Q_L is a quantity index of labor hours for the two types of workers. P_E is an index of the cost of six major types of fuel consumed in each industry: (1) coal and coke, (2) gas fuels, (3) gasoline, (4) fuel oil, (5) electricity, and (6) miscellaneous energy products; Q_E is a quantity index of constant-dollar consumption of the six types of fuel. P_M and Q_M are price and quantity indexes for nonenergy material inputs.

Table 1 summarizes the trends in these indexes over the period 1960–80 and during two subperiods, 1960–72 and 1972–80. Data for the two subperiods are shown in order to highlight the substantial changes that occurred during the early 1970's, particularly the rapid rise in energy prices. The data in the first three rows for each industry are coefficients from log-linear time trend regressions estimated for each of the indexes; the fourth row is the 1960–80 average share of each input in total production cost.

Several features of these estimates are noteworthy. First, with the exception of the price of capital in autos, each of the industries experienced significant input price increases over the period 1960–80. The increases are more dramatic when comparing the two subperiods: The inflation rates in input prices during 1972–80 are often many times the rates during 1960–72.[5] Second, the price of energy increased faster than the prices of the other three inputs, particularly during the 1972–80 subperiod. The prices of labor and nonenergy materials to each industry also rose rapidly during the later subperiod, although labor price increases showed more persistence over the entire period. In fact, during 1960–72, the price of labor rose more rapidly than the prices of capital, energy, or materials in each of the three industries. Finally, when comparing the two subperiods, it can be seen that the rate of change in quantity generally varied inversely with the rate of change in price, indicating a certain amount of price responsiveness in each industry.

How closely does the combination of input prices represented in table 1 reflect output prices in each of the three industries? To answer this question, we constructed a chain-weighted aggregate input price index for each industry using the indexes represented in table 1 and the respective cost shares during 1960–80. The result is a Tornqvist aggregate input price (cost) index, shown as the first column for the respective industry in table 2.[6] The second column for each industry is the corresponding Producer Price Index (PPI), a fixed-weight output price index.[7] The two indexes are highly correlated, as shown by the correlation coefficients at the bottom of the table. The implication is that the appropriate combination of input prices is a good predictor of output prices, in the sense that the same information is contained in both.

Table 1. Average annual percentage changes in prices and quantities, and average cost shares of capital, labor, energy, and materials in three industries, 1960–80

Industry and period	P_K	Q_K	P_L	Q_L	P_E	Q_E	P_M	Q_M
Plastics:								
1960–72	[1]0.6	6.9	4.3	3.6	[1]0.7	12.1	0.6	6.7
1972–80	5.4	2.7	9.8	[1]−0.7	17.3	[1]0.7	13.2	3.0
1960–80	2.7	5.1	6.6	1.6	8.5	6.8	5.5	5.6
Cost shares[2]	.297		.183		.053		.467	
Steel:								
1960–72	[1]0.7	2.1	4.7	[1]0.1	2.9	2.4	2.3	2.5
1972–80	4.8	−0.5	10.9	−2.0	13.9	[1]−1.5	10.0	[1]-0.4
1960–80	3.5	0.8	7.6	−0.8	9.0	1.0	5.2	1.8
Cost shares[2]	.160		.250		.106		.484	
Autos:								
1960–72	[1]2.3	3.5	6.8	[1]1.2	1.2	4.4	2.0	3.9
1972–80	[1]−0.9	5.9	9.8	[1]−0.2	15.0	[1]−0.1	9.5	[1]0.2
1960–80	[1]0.9	4.5	7.7	1.0	7.3	2.8	5.2	2.6
Cost shares[2]	.157		.174		.007		.662	

[1] Trend coefficient not significantly different from zero at the 95-percent confidence level.

[2] Cost shares are the share of each input in total production cost, averaged over the period 1960–80.

Input prices and product inflation

The relationship between input prices and average cost can be described very simply as

$$(1) \qquad C_t = \sum_i P_{it}\,(X_{it}/Q),\; i = K, L, E, M$$

where C_t is average cost in period t; P_{it} is the price of input i in period t; and X_{it}/Q is the physical input-output coefficient of the ith input in period t. The relationship between input and cost inflation rates is found by differentiating equation (1) with respect to time. Assuming a constant rate of output, this reduces to:

$$(2) \qquad \dot{C}_t = \sum_i S_{it}\,\dot{P}_{it},\; i = K, L, E, M$$

where $\dot{C}_t = \Delta C_t / C_{t-1}$; $\dot{P}_{it} = \Delta P_{it} / P_{it-1}$; and $S_{it} =$

Table 2. Aggregate input and output price indexes,[1] three industries,[2] 1960–80
[1972 = 1]

Year	Plastics		Steel		Autos	
	Input prices	Output prices	Input prices	Output prices	Input prices	Output prices
1960	.845	1.156	.746	.739	.699	.837
1961	.834	1.116	.742	.736	.688	.836
1962	.866	1.108	.737	.735	.731	.836
1963	.873	1.094	.770	.738	.748	.829
1964	.901	1.087	.799	.745	.771	.833
1965	.911	1.071	.830	.748	.796	.835
1966	.912	1.074	.839	.758	.792	.836
1967	.875	1.062	.814	.767	.777	.847
1968	.958	1.011	.828	.786	.836	.871
1969	.941	1.006	.867	.824	.860	.888
1970	.909	1.007	.903	.876	.910	.921
1971	.949	.995	.939	.942	.977	.974
1972	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.125	1.023	1.135	1.028	1.041	1.010
1974	1.417	1.417	1.530	1.304	1.153	1.095
1975	1.527	1.657	1.537	1.512	1.282	1.225
1976	1.678	1.759	1.658	1.609	1.445	1.303
1977	1.830	1.816	1.747	1.763	1.554	1.387
1978	1.906	1.857	1.944	1.952	1.676	1.492
1979	2.202	2.133	2.197	2.150	1.786	1.614
1980	2.465	2.497	2.332	2.321	1.821	1.769
Average annual rate of change[1]	5.7	4.3	6.1	6.1	5.0	3.9
Correlation coefficient for annual percent changes	.81		.76		.66	

[1]Output price indexes are BLS Producer Price Indexes.
[2]Computed from a log-linear time trend regression.

$P_{it} X_{it} / C_t$ is the share of the ith input in the total value of output (or cost). Equation (2) makes clear that cost inflation depends upon input price inflation and relative cost shares. For example, if input prices are constant, average cost will be determined solely by the nature of the production technology. In the extreme case of fixed production coefficients, the cost share corresponding to the input with the largest inflation rate will increase and cost inflation will increase proportionately.[8] On the other hand, if the production technology allows for different patterns of input substitution, then share values will vary through time in a manner that reflects substitution away from relatively costly inputs. In this last case, we would expect cost inflation to be lower than for the fixed coefficients case.

To illustrate the importance of factor substitution in cost inflation, we simulated annual inflation rates for three forms of production technology: fixed coefficients, Cobb–Douglas, and one that is consistent with a translog cost function.[9] These three technologies embrace a broad spectrum of factor substitutability. The fixed coefficients case is the most restrictive, disallowing any factor substitution, while the translog cost function imposes no *a priori* restrictions on substitution parameters. The Cobb–Douglas technology is a special case of the translog that permits factor substitution but requires constant factor cost shares.

The three technologies influence cost inflation through equation (2) according to what each implies for the behavior of input cost shares. In the Cobb–Douglas case, input cost shares, and thus the rate of average cost inflation, remain constant through time. For the fixed coefficients technology, share values will depend upon the relative changes in input and average cost inflation. In the translog model, the share values vary from period to period and depend upon the pattern of input prices and the parameters of the cost function. Thus, the translog input cost shares in period t are determined by a share equation of the form:

$$(3) \quad S_{it} = \alpha_i + \sum \gamma_{ij} \ln P_{it} + \gamma_i \ln Q, \ i = K, L, E, M$$

where α_i, γ_{ij}, and γ_i are cost function parameters that must be estimated; and Q is the level of output.

The data underlying tables 1 and 2 were used to estimate the translog cost function parameters. These estimates provide some interesting information on factor substitutability and price responsiveness within each of the three industries. Given the parameters of equation (3), we can immediately calculate price elasticities of demand, $E_{ij} = \partial lnX_i / \partial lnP_j$, for the four inputs. These price elasticities measure the percentage change in the cost-minimizing derived demand for input i in response to a change in the price of input j when gross output and all other input prices are held constant (but after all input quantities have adjusted to new cost-minimizing levels). In general, $E_{ij} \neq E_{ji}$. When $E_{ij}<0$, inputs i and j are substitutes; when $E_{ij}>0$, they are complements; and when $E_{ij}=0$, the inputs are independent.[10]

The input price elasticities of demand for the auto, steel, and plastics industries, shown in table 3, form the basis for a number of conclusions. First, a high percentage of the elasticities are statistically significant, implying a substantial amount of responsiveness to price change. Second, energy demand is highly responsive to a change in its own price in autos and plastics, with own-price elasticities E_{EE} of -1.2 and $-.75$, respectively. Third, labor and capital are substitutes, though only slightly so, in autos and plastics; cross price elasticities E_{KL} and E_{LK} are about .01 in autos and .09 and .14 in plastics. The capital-labor elasticities are somewhat lower than reported in previous studies,[11] although direct comparisons are difficult due to differences in the data and time periods analyzed. Fourth, energy and capital display a substantial complementarity, a finding that is consistent with that reported elsewhere by Ernst Berndt and David Wood.[12] Finally, the cross price elasticities E_{LE} and E_{EL} reveal that energy and labor are complements in all three industries. This result differs from previous findings based on aggregate data, which typically show energy and labor to be substitutes.

Inflation scenarios

We simulated inflation rates for the period 1980–90 under the three assumptions about substitution technology and eight alternative input price scenarios, described below. For a given set of input prices, average cost inflation will be determined by the input cost shares according to equation

Table 3. Estimated input price elasticities of demand based on translog cost function, three industries, 1960–80

Elasticity	Autos	Steel	Plastics
E_{KK}	-.512 (.033)	-.250 (.053)	-.291 (.042)
E_{KL}	[1].010 (.016)	[1]-.005 (.039)	.087 (.009)
E_{KE}	-.034 (.011)	-.117 (.039)	[1]-.027 (.019)
E_{KM}	.535 (.055)	.372 (.115)	.231 (.053)
E_{LK}	[1].009 (.029)	[1]-.003 (.036)	.142 (.028)
E_{LL}	-.522 (.046)	-.496 (.069)	-.257 (.092)
E_{LE}	-.026 (.014)	-.157 (.031)	-.197 (.044)
E_{LM}	.539 (.068)	.657 (.111)	.312 (.096)
E_{EK}	-.709 (.242)	-.176 (.059)	[1]-.153 (.107)
E_{EL}	-.615 (.336)	-.372 (.073)	-.686 (.153)
E_{EE}	1.225 (.435)	[1]-.057 (.077)	-.755 (.190)
E_{EM}	2.547 (.907)	.605 (.157)	1.594 (.268)
E_{MK}	.127 (.013)	.123 (.038)	.147 (.034)
E_{ML}	.141 (.018)	.340 (.057)	.122 (.037)
E_{ME}	.029 (.010)	.132 (.034)	.179 (.030)
E_{MM}	-.297 (.033)	-.595 (.110)	-.448 (.068)

[1]Statistically insignificant at the 90-percent confidence level based on a two-tailed test.

NOTE: Approximate standard errors are shown in parentheses.

(2). The behavior of cost shares, in turn, depends upon the nature of the production technology. Therefore, we begin the inflation simulations by postulating a set of annual inflation rates for each of the four inputs for the period 1981–90. Next, we solve for the equilibrium cost shares in each period according to equation (3) for the translog technology using, as a starting point, the fitted shares for 1980 estimated earlier. We use the same 1980 shares as the base share values for all three technologies. Finally, we use the computed shares to calculate average cost inflation through equation (2). We repeat this procedure seven times, each time beginning with a different set of input price inflation rates.[13]

Our first set of inflation rates consists of the average rates that prevailed for each input during 1972–80: $\dot{P}_K = 5\%$, $\dot{P}_L = 10\%$, $\dot{P}_E = 15\%$, and $\dot{P}_M = 10\%$. In view of the generally high levels of inflation in the economy during the mid- to late seventies this set may be considered an upper reference limit. A lower reference limit is the set that has $\dot{P}_L = \dot{P}_E = 0$. For all scenarios we hold $\dot{P}_K = 5\%$ and focus mainly on variations in $\dot{P}_L$ and $\dot{P}_E$.[14]

Table 4 presents the simulated cost inflation rates for the year 1990. The end-of-simulation-period results should highlight any differences that exist among the various scenarios. Notice first that if the input price inflation that prevailed during the 1970's were to continue through the 1980's, substantial cost inflation would result in the three manufacturing industries studied. Although this scenario may now seem unlikely, such rapid price increases at this stage of processing would stimulate inflationary pressure throughout many sectors of the economy.

The effect on cost inflation of differences in factor substitutability is assessed by reading across the rows of table 4 for each industry. The most striking finding is that there appear to be relatively small differences across the three production technologies. Only in scenarios 5, 7, and 8 do we observe more than a 1-percentage-point difference in inflation rates, and the first two scenarios involve rather extreme assumptions concerning input price inflation. The implication for the analysis of inflation is that factor substitutability has little effect.

Table 4 shows that cost inflation generally is lowest under the Cobb–Douglas technology and, as expected, is highest under the fixed coefficients technology (except as noted in footnote 1 to table 4). Both technologies represent models that are *a priori* more restrictive than the translog. The translog function is a highly flexible form that does not

Table 4. Simulations of average cost inflation in 1990 for alternative cost functions and input price changes, three industries

Scenario	Percent change in input prices				Annual percent change in average costs, 1990								
					Plastics			Steel			Autos		
	$\dot{P}_K$	$\dot{P}_L$	$\dot{P}_E$	$\dot{P}_M$	Fixed coefficients	Cobb-Douglas	Translog	Fixed coefficients	Cobb-Douglas	Translog	Fixed coefficients	Cobb-Douglas	Translog
1	5.0	10.0	15.0	10.0	9.5	8.9	9.3	10.4	9.9	10.4	9.1	8.9	9.0
2	5.0	10.0	7.5	10.0	8.6	8.3	8.5	8.9	8.7	8.9	9.1	8.9	8.9
3	5.0	10.0	0.0	10.0	8.4	7.7	7.9	8.4	7.4	8.1	9.1	8.8	8.9
4	5.0	5.0	15.0	10.0	9.0	8.2	8.9	9.7	8.8	9.5	8.5	8.1	8.2
5	5.0	0.0	15.0	10.0	8.8	7.5	[1]8.9	9.5	7.6	8.8	8.3	7.1	7.6
6	5.0	5.0	7.5	10.0	8.1	7.7	7.9	8.0	7.6	7.6	8.4	8.0	8.1
7	5.0	0.0	0.0	10.0	7.6	6.3	6.3	7.0	5.2	4.9	8.2	7.1	7.3
8	5.0	10.0	15.0	5.0	7.3	6.3	6.2	8.8	7.5	7.8	6.1	5.7	5.8

[1]The translog is expected to be lower than the fixed coefficient rate. It is not the case here, perhaps because of the extreme assumptions concerning input prices.

restrict substitution elasticities and permits Cobb–Douglas and fixed coefficients hypotheses as special cases. The estimated translog cost function produced cross elasticities of substitution for each industry (data not shown) that are significantly positive and significantly less than 1, leading to the rejection of both the fixed coefficients and the Cobb–Douglas hypotheses. The implications of this result are that: 1) the high rates shown in table 4 for the fixed coefficients model are the result of disallowing any factor substitution; and 2) the low rates for the Cobb-Douglas model result from imposing more substitution than actually occurs in these industries as revealed by the translog estimates. Nevertheless, the differences that do occur among the three technologies are small.

The effect on cost inflation of alternative input price inflation rates can be seen by reading down the columns of table 4. The first three rows indicate the effect of different (assumed) rates of growth in energy prices (15%, 7.5%, 0%). For the auto industry there is virtually no effect on average cost, which is indicative of the very small share (less than 1%) that energy costs are of total production costs. Growth rates in energy prices have a greater effect on average cost in the plastics and steel industries. For example, with the translog technology, the difference between a 7.5- and a 15-percent increase in energy prices is a 0.8- and a 1.5-percentage-point difference in cost inflation in plastics and steel, respectively. The largest impact of energy price increases occurs in the steel industry. With the translog technology, the difference between no change in the growth rate of energy prices and a 15-percent increase is 2.3 percentage points in the growth rate of average cost.

The effect on changes in average cost of differences in the growth of labor prices can be seen by comparing rows 1, 4, and 5 in table 4; the effects of differences in both energy and labor prices appear in rows 1, 6, and 7. For comparable differences in rates of growth, labor prices generally have a smaller effect than energy prices on cost change in the plastics industry; the opposite occurs in autos. For example, under the translog technology, a 10-percentage-point difference in $\dot{P}_L$ is reflected in a 0.4- and a 1.4-percentage-point difference in cost inflation in plastics and autos, respectively. The auto industry is the only one of the three to experience a rising labor cost *share* over the period 1960–80. As indicated in table 1, the auto industry shows virtually no trend during 1972–80 in its use of labor input, despite the substantial labor price increases that occurred during that period. In the steel industry, energy prices also have a greater effect than labor prices, particularly at low rates of input price change: a 10-percentage-point difference in $\dot{P}_L$ has only a slightly smaller effect than a 15-percentage-point difference in $\dot{P}_E$.

Finally, nonenergy material inputs make up the largest share of total production costs in each industry. For that reason, we show in row 8 of table 4 the effect of a 5-percentage-point difference in the growth of $\dot{P}_M$ (compared to row 1). As might be expected, differences in the cost inflation rates are substantial for each industry. Sustained increases in the prices of nonenergy material inputs would have dramatic consequences for the transmission of inflation that would not be avoided by the substitution of other major inputs.

In summary, the transmission of input to average cost inflation differs by industry and appears to occur primarily through differences in input price inflation; factor substitution plays a minor role.[15] The conclusion that the effects differ by industry is, of course, not surprising; yet it warns against drawing inferences from an analysis of more aggregate data. It also implies that the prospects for controlling or reducing inflation would depend upon rather finely targeted policies. For example, significant gains could be achieved from policies that help hold down energy prices to the plastics and steel industries and labor costs in the steel and auto industries. Such conclusions, of course, need to be verified with a broader set of industries. □

——*FOOTNOTES*——

[1] The detailed components of the industries studied are presented in the *Standard Industrial Classification Manual*, prepared by the U.S. Office of Management and Budget. Autos (SIC 371) comprises manufacturers of motor vehicles and passenger car bodies; truck and bus bodies; motor vehicle parts and accessories; and truck trailers. Steel (SIC 331) covers blast furnaces, steel works, and rolling and finishing mills; electrometallurgical products; steel wire drawing and steel nails and spikes; cold rolled steel sheet, strip, and bars; and steel pipe and tubes. Plastics (SIC 282) covers the manufacture of plastics materials, synthetic resins, and nonvulcanizable elastomers; synthetic rubber (vulcanizable elastomers); and manmade fibers.

[2] Ernst Berndt and David Wood, "Technology, Prices, and the Derived Demand for Energy," *Review of Economics and Statistics*, August 1975, pp. 259–68, is an early paper to which our work is directly related. Other examples include Robert Halvorsen and Jay Ford, "Substitution Among Energy, Capital, and Labor Inputs," in Robert Pindyck, ed., *Advances in the Economics of Energy and Resources* (Greenwich, CT, JAI Press, 1979), pp.27–50; Melvyn Fuss, "The Demand for Energy in Canadian Manufacturing," *Journal of Econometrics*, vol. 5, 1977, pp. 89–116; John Norsworthy and Michael Harper, "Productivity Growth in Manufacturing in the 1980s: Labor, Capital, and Energy," *American Statistical Association, Proceedings of the Business and Economic Statistics Section* (1980), pp. 17–26; and Robert Pindyck, "Interfuel Substitution and the Industrial Demand for Energy: An International Comparison," *The Review of Economics and Statistics*, May 1979, pp. 169–79.

[3] A similar type of analysis for the period 1954–71 is reported in John Moroney and Alden Toevs, "Input Prices, Substitution, and Product Inflation," in Pindyck, ed., *Advances in the Economics*, pp. 27–50; and John Moroney and John Trapani, "Factor Demand and Substitution in Mineral-Intensive Industries," *Bell Journal of Economics*, Spring 1981, pp. 272–83. In both articles, only three factors are considered: capital, labor, and natural resources (including energy).

[4] Erwin Diewert, "Aggregation Problems in the Measurement of Capital," in Dan Usher, ed., *The Measurement of Capital* (Cambridge, MA, National Bureau of Economic Research, Studies in Income and Wealth, 1980), pp. 433–528, argues for the inclusion of inventories in the measurement of capital input. Frank Gollop and Dale Jorgenson, "U.S. Productivity Growth by Industry," in John Kendrick and Beatrice Vaccara,

eds., *New Developments in Productivity Measurement* (Cambridge, MA, National Bureau of Economic Research, 1980), pp. 17–124, follow this procedure.

[5] The substantial differences between the two subperiods suggest that the industries are operating under separate regimes in 1960–72 and 1972–80. A more detailed study would examine this possibility.

[6] The chained Tornqvist index in period t is:

$$P_t/P_{it-1} = \Pi\ (P_{it}/P_{t-1})^{**}(1/2(S_{it} + S_{it-1}))$$

where $i = K,L,E,M$; and S_i is the cost share of the ith input. Erwin Diewert, "Exact and Superlative Index Numbers," *Journal of Econometrics*, May 1976, pp. 115–46, has shown that this index is exact for the translog cost function.

[7] The corresponding industries and Producer Price Indexes (PPI's): Steel (SIC 331): 10–17, Steel Mill Products; Autos (SIC 371): 14–1, Motor Vehicles and Equipment. A corresponding PPI for SIC 282 is not available. To approximate an index for this industry, we aggregated the PPI's 06–6 (Plastic Materials and Resins), corresponding to SIC 2821; 07–11–02 (Synthetic Rubber), corresponding to SIC 2822; and 03–1 (Synthetic Fibers), corresponding to SIC 2823–24. Further, because there is no published index for 03–1 prior to 1976, we approximated this component by aggregating 03–31–02 (Cellulosic, Staple, and Tow) and 03–32–02 (Noncellulosic Yarns) for the earlier years.

[8] At the limit, the value of the share will approach 1 and cost inflation will equal input inflation.

[9] The translog (Transcendental Logarithmic) function was introduced in Laurence Christensen, Dale Jorgenson, and Laurence Lau, "Transcendental Logarithmic Production Frontiers," *Review of Economics and Statistics*, February 1973, pp. 28–45, and has since been applied widely in the study of industrial production.

[10] A well-behaved cost function requires that "own-price" elasticities, E_{ii}, be less than zero. Given the estimates for the parameters in equation (3) of the text, the elasticities are calculated as:

$$E_{ii} = (S_i^2 - S_i + \hat{\gamma}_{ii})/S_i \quad \text{and}$$

$$E_{ij} = (S_iS_j + \hat{\gamma}_{ij})/S_i$$

Table 2 reveals that $E_{ii}<0$ for each factor. Approximate standard errors for elasticity estimates are computed as:

$$SE(\hat{E}_{ii}) = SE(\hat{\gamma}_{ii})/\hat{S}_i;$$

and

$$SE(\hat{E}_{ii}) = SE(\hat{\gamma}_{ii})/\hat{S}_i;$$

where *SE* stands for standard error. The data in table 3 are based on estimated shares, averaged over the sample period.

[11] See, for example, Berndt and Wood, "Technology, Prices, and the Derived Demand."

[12] The issue of whether capital and energy are complements or substitutes is unsettled in the literature. Berndt and Wood, "Technology, Prices, and Derived Demand," and Fuss, "The Demand for Energy," for example, find energy and capital to be strong complements. James Griffin and Paul R. Gregory, "An Intercountry Translog Model of Energy Substitution Responses," *American Economic Review*, December 1981, pp. 1100–04, and Pindyck, "Interfuel Substitution," report evidence of substitutability. For further discussion, see Berndt and Wood, "Engineering and Econometric Interpretation of Energy Capital Complementarity: Reply and Further Results," *American Economic Review*, December 1981, pp. 1105–10; and Griffin, "Engineering and Economic Interpretations of Energy-Capital Complementarity: Comment," *American Economic Review*, December 1981, pp. 1100–04. It should also be pointed out that, when data for individual industries are used, elasticities vary substantially for all inputs, as in Halvorsen and Ford, "Substitution Among Energy, Capital, and Labor Inputs"; Moroney and Toevs, "Input Prices"; and Moroney and Trapani, "Factor Demand." We should expect factor substitutability to differ across industries, and our results bear this out.

[13] It should be emphasized that we are not forecasting inflation in the three industries according to what is most likely to occur during the 1980s; we are providing alternative scenarios that demonstrate the importance of input price inflation and factor substitutability.

[14] For convenience, the scenarios were generated holding output at its 1980 level.

[15] Moroney and Toevs, "Input Prices," come to a similar conclusion.