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INVESTMENT IN CAPITAL ASSETS AND ECONOMIC PERFORMANCE: THE U.S. CHEMICALS AND PRIMARY METALS INDUSTRIES IN TRANSITION

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ABSTRACT

The effects of market and technological conditions on the investment and markup behavior of firms, and their resulting impacts on economic performance, are closely interrelated and complex. In this paper determinants of and linkages among these are explored for two industries with very different performance records and development patterns over the past three decades -- the chemicals and primary metals industries. The analysis is carried out using a production theory model that permits explicit assessment of the motivations underlying firm decisions, based on BLS data from 1955-86.

General capital (K) investments are distinguished from investments in innovative or high tech capital such as office and communications equipment (O) and technical and scientific apparatus (S). Investment behavior and thus capacity utilization are explicitly modeled as responses to adjustment costs for capital assets. This approach facilitates the measurement of technological and behavioral factors underlying investment, input demand and pricing decisions. This in turn allows investment patterns and their determinants across capital assets to be interpreted, and their linkages with productive and financial performance to be identified.

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I. Introduction

Compositional changes in capital investment have been widespread in the past two decades as high-tech capital has increasingly diffused into U.S. manufacturing processes. If the underlying investment decisions are being carried out effectively -- in terms of appropriately balancing the different types of capital accumulation given observed economic factors -- this dispersion of new technology should improve the economic performance of firms. One might expect, for example, enhanced productivity growth and profitability. Firms might also exhibit more efficient utilization of capacity, and perhaps even expansion of potential scale economies due to increasingly rapid dissemination of information facilitated by high-tech equipment.

The performance consequences of investment in different capital assets have been a source of many hypotheses and some controversy. A number of insights about these interrelationships were provided in Dertouzos, Lester and Solow [1990], where the history of firms' responses to changing market forces and resulting economic performance patterns is examined for several U.S. manufacturing industries. Their treatment highlights the importance of interactions among alternative types of investment decisions, profitability and productivity. It also underscores, however, the difficulties involved in analyzing these linkages and their determinants, for they are tricky to untangle.

A different perspective on these issues that facilitates this untangling involves a more structural approach. In particular, a structural production theory framework allows explicit representation of technological and market configurations of firms. Investment decisions for different assets, stimulated by a complicated pattern of technological and market motivations, may thus be evaluated in detail in such a framework. In addition, the interactions of such investment with pricing and other firm behavior may be modeled and assessed. Production theory-oriented studies evaluating investment patterns and resulting capacity utilization, productivity growth, pricing and profitability have demonstrated important potential to analyze these interactions.[1]

In this study such a model is used to consider the causes and effects of high-tech capital investment, and to evaluate associated economic performance for the U.S. chemicals (CM) and primary metals (PM) industries from 1955 to 1986. These industries are both capital intensive and have experienced increasing import competitiveness, yet each has exhibited very different firm behavior and performance patterns. The approach used to compare these patterns shows how a production theory model can be used to assess quantitatively the performance determinants identified using more qualitative case-study type methods. Specifically, it allows measurement and evaluation of a number of performance indicators -- including investment and capacity utilization, markups and profitability, and productivity growth -- and their determinants.

A distinction is made between investments in general capital equipment and those for innovative or high-tech capital, the latter of which is in turn divided into office and communications equipment (including computers) and technical and scientific apparatus (encompassing capital expenditures for research and development). The general patterns of investment and economic performance identified for the two industries under consideration reflect consequential variations between industries with dissimilar development patterns. Although investment patterns in the two industries are roughly comparable, utilization patterns, technological characteristics and productive and financial performance differ in important ways.

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[1] See, for example, Morrison [1989], and Morrison and Berndt [1991] and the references contained in these studies.

Lower investment by the PM industry in scientific equipment during this time period was justifiable, in the sense there was less scope for such investment. Strong investment in the 1980s for both industries in office and communications equipment seemed particularly beneficial for the chemicals industry due to increased output demand, although the economic incentive diminished by the end of the sample. Utilization in the chemicals industry, was higher than in the PM industry, but did not seem to increase to the extent often suggested. The composition of input use changed more for the CM industry over time, possibly due to greater substitution flexibility, leaving capacity utilization fairly flat, even with decreases in capital intensity.

Overall, investment responses in the primary metals industry had somewhat different motivations and effects than those for the CM industry. Economic conditions were more harmful to this industry due the greater impact of energy price increases and import competition, and to lack of flexibility to market changes. This caused financial performance to decrease, at least in part from problems caused by short term fixity, reduced potential to take advantage of scale economies and declines in market power. Productive performance also declined due to these technological and market conditions, although when standard productivity growth measures are adapted to appropriately capture these production characteristics it appears that productivity growth downturns have been exaggerated in primary metals, and understated in the chemicals industry.

II. Characteristics of the Industries

The primary metals and chemical industries in the U.S. have experienced widely divergent patterns of behavior and performance in the past two decades. Evidence of this has emerged in a number of studies based on two-digit manufacturing data, including Baily and Hulten [1990], who show that these industries have in some senses been outliers in terms of productivity performance, and Dertouzos et al. [1990] who evaluate these industries in great detail.

Dertouzos et al. identify a number of characteristics of the PM and CM industries which impact on evaluation of their economic performance. Although both industries are capital intensive, the primary metals industry has been significantly less research intensive, particularly since the early 1980s. The financial and productive performance of the PM industry has also declined quite steadily, although that for the chemicals industry rebounded at least somewhat in the 1980s after a prominent decline. Also, competitiveness from international expansion of markets was significant in both these industries, but the PM industry appears to have suffered more critically from this, especially recently.

More specifically, as documented in the Dertouzos study, from 1975-85 the primary metals industry experienced declining demand, loss of market share, a substantial decline in production and employment, and low or negative earnings. The problems identified to explain this included increasing foreign competition, high and increasing labor and energy costs, and government interference resulting in constraints on price increases. These events discouraged investment, and thus this industry has been characterized by only partially modernized plants. The low investment was also due to a lack of financial capital for investment purposes; according to Dertouzos et al., R&D was particularly hard hit over time because of its long-term horizon.

A different pattern occurred in the chemicals industry. The expansion and increasing profitability evident in this industry during the 1960s was reversed in the 1970s, stimulating a slowdown that proceeded to become more serious later in the decade (especially after 1978), at which time innovation, employment, productivity and profitability all declined dramatically. This was due at least partly to increasing competition in the industry arising from a general weakening of demand as well as from imports. In addition, difficulties emanated from increasing costs of energy (which included feedstocks and exacerbated overcapacity problems), as well as "growing technological maturity". More recently, however, since the early 1980s a recovery appears to have begun, possibly stimulated by increasing innovation and investment in R&D. Specialization, due perhaps in part to an increased ability to maintain market power and thus markups, appears to be on the upswing. The selling of excess capacity, or at least reduced investment in plant and machinery, has also been observed.

Evaluation of the behavior underlying these types of patterns requires a model of firm decisions that allows explicit representation of the demand and cost factors generating the fluctuations. Such a model should permit measurement of technological and market characteristics motivating firm decisions involving investment, capacity utilization, markups, profitability and productivity, which together establish productive and financial performance. Causes of cost and demand fluctuations facing the firm such as variations in input prices and import competition must also be incorporated to determine their effects. These can be thought of as explicit cost and demand "shocks" affecting firm behavior and thus performance.

The construction of a model including such an elaborate pattern of responses requires a solid theoretical structure. One type of model capable of capturing these different factors is a production-theory-based structural model. In the next section such a model is outlined, and its potential to model, measure and evaluate these facets of economic performance is then considered.

III. The Model and Resulting Indicators of Economic Performance

The model used to generate the empirical results presented in the next section was developed in Morrison [1988,1989]. The primary difference here is that labor is considered a variable input and a distinction is made among the different capital stocks, all modeled as quasi-fixed due to adjustment costs.

The structure of the model is based on variants of generalized Leontief (variable) cost and output demand functions. The cost function takes the general form $G(Y,t,\mathbf{x},\Delta\mathbf{x},p)$ where **x** and Δ**x** denote levels of and investment in the fixed inputs (here the three types of capital -- K, S and O representing general, scientific and office capital equipment), p is a vector of the prices of variable inputs (energy, E, intermediate materials, M, purchased services, PS and labor, L), Y is output, t is a time counter representing technical progress, and the inclusion of Δ**x** allows for internal costs of adjustment on capital assets. The inverse demand function for output is specified as $p_Y(Y,EXP,p_I,r,p_{CPI},UN,IMPRAT,t)$ where EXP is overall expenditure per person in the economy, p_I represents import prices, p_{CPI} reflects the general price level in the economy and UN is unemployment, as elaborated in Morrison [1989]. For our purposes IMPRAT -- the ratio of imports to domestic production ($IMPRAT=p_I\cdot IMP/p_Y\cdot Y$ where IMP is constant dollar imports of the produced good) -- was added as an argument of the function to capture the impacts of import competitiveness.

These functions can be written explicitly as:

$$1)\ G(Y,t,\mathbf{x},\Delta x,p) = Y[\textstyle\sum_i\sum_j \alpha_{ij}\, p_i^{.5}\, p_j^{.5} + \sum_i\sum_m \delta_{im}\, p_i\, s_m^{.5} + \sum_i p_i \sum_m\sum_n \gamma_{mn} s_m^{.5}\, s_n^{.5}]$$

$$+\ Y^{.5}[\textstyle\sum_i\sum_k \delta_{ik}\, p_i\, x_k^{.5} + \sum_i p_i \sum_m\sum_k \gamma_{mk} s_m^{.5}\, x_k^{.5}] + \sum_i p_i \sum_k\sum_l \gamma_{lk} x_k^{.5} x_l^{.5}\ ,$$

$$2)\quad p_Y(EXP, p_{IM}, r, p_{CPI}, Y, UN, t) = \left[\frac{\sum_h \beta_{Yh} \rho_h^{.5}}{Y - \beta_{YU} UN - \beta_{Yt} t}\right]^2$$

where x_l, x_k denotes the fixed inputs, p_i and p_j index the prices of variable inputs, s_m, s_n depict the remaining arguments of $G(\cdot)$ $(Y, t, \Delta x_k)$, and ρ_h represents the vector of demand determinants.

These expressions capture a wide range of factors motivating behavior, since any change in arguments of these functions causes a shift in the cost or demand functions, which works through the decision process to alter firm behavior and affect economic performance. This richness of the explicit specification of decision patterns is reflected in the estimating equations from this model, which stem from the cost and demand functions.

An eight-equation system of estimating equations was developed for empirical implementation, to represent input demand, investment and price setting behavior. Four input demand equations are derived from Shephard's lemma as $\partial G/\partial p_i = v_i$ (where v_i is demand for variable input i, i=E,M,PS,L). Three investment equations are specified by Euler equations that capture the difference between the market price p_k and the shadow value $Z_k = -\partial G/\partial x_k$ of any capital asset x_k (k=K,S,O), and reflect the investment response to this deviation.[2] Finally, a price determination equation is derived from the standard profit maximizing equality between marginal revenue and marginal cost, expressed as $MR = p_Y + Y \cdot \partial p_Y/\partial Y = \partial G/\partial Y = MC$.

From the data and the parameters of these estimating equations indicators representing investment motivations, pricing and input demand can

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[2] See Berndt Fuss and Waverman [1980] or Morrison and Berndt [1981] for an elaboration of the development of such equations, based on Treadway [1974]. Essentially these equations represent the adjustment costs causing the gap between p_k and Z_k in subequilibrium, since the firm would adjust investment to make these two values equal if instantaneous adjustment were feasible. The actual investment is therefore a partial adjustment of the capital stock toward its "desired" level (equalizing these values), which is limited by the costs imposed by rapid adjustment.

be generated directly, and their responsiveness to changes in the exogenous variables computed through elasticities. In addition, however, these estimates allow indexes of economic performance and their determinants to be measured. To consider the issues of investment and economic performance raised by researchers such as Dertouzos et al., some of the most useful such measures are indexes of output and import levels; capital-to-output, investment-to-stock and shadow-to-market-price ratios for the different types of capital assets; capacity utilization and returns to scale indicators; markup and profitability measures; and productivity growth indexes.

Import and output indexes (or their ratio), and capital-to-output and investment-to-stock ratios may be derived directly from the data. They are also self-explanatory; they reflect changes in international competitiveness and demand, overall capital intensity and differential patterns of investment by asset and industry, respectively. However, the construction and use of the other indicators requires more motivation, since they must be computed and interpreted within the context of the full structural model.

Shadow value ratios are designed to be input-specific versions of (marginal) Tobin's q. Define the marginal shadow value to be $Z_k=-\partial G/\partial x_k$ -- the savings on variable inputs allowed by a marginal increase in x_k. Then Z_k/p_k' will fall short of one to the extent that the value to the firm of an addition to the asset stock is less than the market price, and vice versa for $Z_k/p_k'>1$, where $p_k'=p_k+r\dot{G}_k$.[3] This allows consideration of investment motivations, and thus whether investment in the various x_k assets appears to be optimal, or justified in terms of the differential marginal values of their stocks.

[3] See Morrison and Berndt [1991] for further elaboration. Essentially this "q"-ratio is defined in terms of p_k' rather than p_k because when the dynamics are explicitly incorporated, the steady state is defined in terms of the equality of Z_k and p_k', since p_k' includes the amortized adjustment costs occurred by moving to this point -- it represents the full dynamic user cost.

The determinants of the levels and changes in these values may also be assessed, through the dependence of G(•) on exogenous variables such as labor and energy prices. This dependence implies an explicit form for the response of Z_k to changes in these factors, which can be expressed in elasticity form as, for example, $\partial\ln Z_k/\partial\ln p_i$.

Capacity utilization (CU) measures result directly from the shadow value measures since they represent subequilibrium -- over or underutilization of the fixed factors as compared to their optimal utilization level. As discussed in a number of recent studies including Morrison [1988], a cost-side capacity utilization measure may be generated as $CU_c=C^*/C =(G+\sum_k Z_k x_k)/(G+\sum_k p_k' x_k)$. This measure summarizes the extent of fixity of the quasi-fixed factors as a whole, which is useful for evaluating overall investment incentives, and as a basis to investigate the causes of utilization changes through the dependence of the Z_ks on exogenous factors. For example, the decline in investment and associated increase in utilization in the late 1980s in the chemical industry posited by Dertouzos <u>et al.</u> can be measured, and their determinants identified, using these measures. In addition, the CU_c measure facilitates analysis of the extent utilization impinges on short term productivity growth (as elaborated further below)

The cost elasticity $\epsilon_{CY}=\partial\ln C/\partial\ln Y$ also may be computed; this reflects both utilization and scale economies through the definition $\epsilon_{CY}=CU_c\epsilon_{CY}{}^L$ (as shown in Morrison [1989]), where L denotes the long run and $1/\epsilon_{CY}{}^L$ measures long run returns to scale. The $\epsilon_{CY}{}^L$ elasticity represents the slope of the long run average cost curve, whereas CU_c reflects the shape of the short run average cost curve. A combination of the two determines the observed cost change.

The implications for scale effects on performance, although not directly addressed in most qualitative studies of economic performance, have an important impact on the interpretation of productivity growth measures since cost changes due solely to fixities and output growth given the existing technology, as well as those from technical change may be captured in the productivity growth measure. These effects will also influence financial performance through their impact on cost effectiveness.

More specifically, profitability, and thus financial performance, is determined by the divergence between average cost and price. This is a combination of the difference between average and marginal cost, resulting from fixities and scale, and the difference between price and marginal cost, due to market power and pricing decisions. To formalize this, ϵ_{CY} can be written as $\epsilon_{CY}=\partial\ln C/\partial\ln Y=\partial C/\partial Y\cdot(Y/C)=\partial G/\partial Y\cdot(Y/C)=MC/AC$, where MC is marginal cost and AC is average cost. The markup may simply be expressed as $MKP=p_Y/MC$ where $p_Y=\partial G/\partial Y-Y\cdot\partial p_Y/\partial Y$ and $MC=\partial G/\partial Y$. Thus, profitability (the ratio of revenues and total cost) can be computed as $(p_Y/MC)\cdot\epsilon_{CY}=MKP\cdot\epsilon_{CY}$,

Since these measures depend explicitly on exogenous determinants of demand and cost such as import prices and input costs, fluctuations in financial performance and their causes can be assessed. For example, the patterns of earnings observed by Dertouzos _et al._ in different industries may directly be compared and their determinants untangled. In addition, the extent of markups in the different industries provides some evidence about possible constraints on pricing behavior and competitiveness among industries.

Productive performance may also be evaluated by constructing traditional cost-side productivity growth indexes, denoted ϵ_{Ct} since they are based on the notion of the cost-responsiveness of firms to technical changes (which can be expressed in elasticity form as $\epsilon_{Ct}=-\partial\ln C/\partial t$). These may be computed and adjustments made to accommodate and correct for utilization changes (resulting in the adapted measure $\epsilon_{Ct}{}^{F}$), or to also include scale effects (to generate $\epsilon_{Ct}{}^{T}$), as developed in Morrison [1989]. This final measure represents the pure technical change or innovation effect, independent of utilization and scale; this allows decomposition of the overall productive performance measure into its determinants.

This overview of indicators that may be constructed from the production theory model establishes the rich basis provided by the model for assessing the interactions of exogenous changes in the economic climate, firm decisions such as investment, and economic performance. With this basis, we can now focus on measures of these indicators, and determine how they can be used to facilitate understanding of the fluctuations in economic performance experienced by the PM and CM industries from 1952 to 1986.

IV. The Findings

The measures presented in this section were generated using output and input price and quantity data for the primary metals and chemicals industries from the Bureau of Labor Statistics Productivity Division, graciously provided by Michael Harper. The capital data were reconstructed from their components to reflect ex-ante market prices, and to break down the stock into the three different components (K, S and O).[4] Data for most arguments of the demand function are from the 1990 Economic Report of the President, as elaborated in Morrison [1989]. Data on imports are from the Statistical Abstract of the U.S., U.S. Department of Commerce.

Estimation of the eight-equation system outlined above was carried out using iterative three stage least squares, with instruments including lagged values of the exogenous cost and demand arguments, as well as the world oil

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[4] O is a Divisia index of two asset codes in the BEA data set: 14 -- office, computing and accounting machinery (including computing and related machines, typewriters, scales and balances and office machines not elsewhere classified); and 16 -- communications equipment. S is a similarly constructed aggregate of: 25 -- scientific and engineering instruments; and 26 -- photocopy and related equipment. K is a measure of all remaining capital equipment.

price, presidential party, and defense spending variables used by Hall [1986] as instruments for demand shocks. Estimation was carried out separately for the two industries in order to minimize the common structure imposed. In the following subsections, the data on industry differences in market conditions and investment patterns will first be analyzed, and then the causes and determinants of these patterns will be evaluated in terms of measures of investment incentives and economic performance constructed from the parameter estimates.

IVa. Evidence on Market Conditions and Investment Behavior

As a basis for our analysis, a first issue to explore is the similarities and differences between the industries in terms of market conditions and firm behavior. For example, increasing energy and labor prices, and especially import competition have been identified by Dertouzos *et al.* as important economic pressures facing firms in these industries. Also, differences in capital intensity and investment responses, which have a large role in determining economic performance, have been highlighted as important factors affecting observed economic performance. To assess these issues requires first considering the evidence about these conditions.

As can be seen in Table 1, indexes of input prices indicate that labor and particularly energy prices facing both industries increased substantially, but differences between the industries are negligible. By contrast, variations in import competition, which is perhaps the one most important pressure on the industries, are substantial. In Table 1 this is documented in terms of the output and import levels and ratios (market shares) of imported to domestic production. All these measures are presented at five year intervals from 1955 to 1985, as well as in terms of their percentage average annual growth rate (AAGR) from 1955 to 1985.

Table 1: Input Prices and Import Share

Energy and Labor Prices (1971-1.0)

	Primary Metals		Chemicals	
Year	P_E	P_L	P_E	P_L
1955	.779	.479	.737	.471
1960	.859	.625	.756	.615
1965	.801	.704	.772	.740
1970	.901	.924	.925	.943
1975	2.039	1.534	2.238	1.476
1980	4.082	2.431	4.734	2.261
1985	5.977	2.923	6.813	3.080
AAGR (%)	7.03	6.21	7.70	6.46

Output and Import Values and Import Ratio

	Primary Metals			Chemicals		
	Y	IMP	IMPRAT	Y	IMP	IMPRAT
1955	23.53	11.85	.504	15.68	4.18	.267
1960	23.26	13.80	.593	20.26	8.17	.403
1965	31.33	28.74	.917	27.86	7.68	.276
1970	38.26	45.08	1.178	38.06	14.50	.381
1975	63.34	89.44	1.412	69.34	36.96	.533
1980	102.99	180.27	1.750	124.06	70.03	.564
1985	85.20	204.39	2.399	153.54	127.90	.833
AAGR (%)	4.38	9.96	5.34	7.90	12.08	3.87

The market share numbers are dramatic evidence of the increasing impact of imports on these industries, particularly for the PM industry in which the value of imports increased from about 50% of domestic production in 1955 to 250% in 1985, when domestic production actually dropped. The value of imports grew even faster in the chemicals industry, but demand increased rapidly enough that expansion of the domestic market followed more closely; imports accounted for less than half of the market even in 1985. The average annual growth rates summarize these patterns -- in total the import ratio increased over five percent per year for PM, whereas the ratio increased less than four percent for CM, with output increases averaging almost double that for PM.

In Table 2, capital-output ratios, representing asset-specific capital intensity, are presented. These numbers are useful for identifying variations in innovation rates between these industries, in terms of enhancing the capital available for use by workers, and as a partial indicator of how energy price increases might have affected the industries. The ratios indicate a higher capital intensity overall in the CM than the PM industry in the early years, which reversed by the end of the sample given the substantial drop in capital-intensity for chemicals companies and increase in primary metals. Thus, higher energy prices would likely have had a more harmful impact on the PM industry by the end of the period. By this time, also, the composition of the capital stock had changed; the S-intensity was much greater in the CM industry, and the proportion of O-equipment was substantially greater in the

Table 2: Capital to Output Ratios

	Primary Metals			Chemicals		
Year	K/Y	S/Y	O/Y	K/Y	S/Y	O/Y
1955	1.226	.034	.051	2.462	.195	.113
1960	1.561	.039	.075	1.907	.135	.100
1965	1.374	.033	.053	1.667	.165	.080
1970	1.441	.028	.045	1.326	.142	.045
1975	1.456	.055	.057	1.314	.309	.040
1980	1.368	.131	.092	1.085	.514	.064
1985	1.820	.223	.232	1.046	.624	.137
AAGR (%)	1.33	6.47	5.18	-2.81	3.95	.64

PM industry, indicating substantial investment in high-tech capital, but quite different patterns across assets.

Higher and increasing research-intensity in the CM industry seems evident by the high S/Y ratio; the level was always much higher than for PM and most of the growth occurred post-1975. This is consistent with the stronger CM industry response to import competitiveness in terms of innovations and R&D suggested by Dertouzos et al.. The declining capital intensity in the CM industry, especially for the K component, also appears to confirm that utilization increased in chemicals companies late in this period, although, as we will see below, it may instead imply greater factor substitution possibilities given market conditions.

The pattern of the office and communiciations equipment component is particularly interesting. The O/Y ratio declined to 1975, especially for CM, and then increased dramatically for both industries. Specifically, in the post-1975 period, the ratio doubled by 1980 and more than doubled again by 1985 for PM, whereas it increased by 50% to 1980 and doubled to 1985 in the CM industry. Since there is some evidence (see Berndt and Morrison [1991]) that this type of investment does not pay off in terms of cost savings, this may be a factor involved in the PM industry's apparently floundering relative economic performance. Similarly, it is not clear whether the heavier S-capital investment in the CM industry provided sufficient returns to expedite greater performance. The shadow values presented below will facilitate further assessment of the effectiveness of this investment.

The information in Table 3 on patterns of gross investment for different assets (in terms of both the growth rates for each asset and the shares of each in total investment) highlights some of the tendencies suggested by the data in Table 2. Investment exhibited somewhat diverse patterns for the PM and CM industries, although important similarities stand out. The PM industry is less research intensive than the CM industry, for example, in the sense that investment in S tends to be a smaller proportion of the total.[5] However, the growth rates in investment across the industries are surprisingly similar.

Table 3: Gross Investment Ratios and Shares of Total

	Primary Metals			Chemicals		
Year	$\Delta K/K$	$\Delta S/S$	$\Delta O/O$	$\Delta K/K$	$\Delta S/S$	$\Delta O/O$
1955	.073	.041	.068	.066	.041	.057
1960	.088	.100	.111	.090	.113	.197
1965	.114	.113	.099	.138	.181	.102
1970	.113	.136	.138	.142	.172	.110
1975	.122	.402	.224	.147	.380	.230
1980	.114	.261	.283	.121	.232	.246
1985	.065	.116	.263	.089	.167	.282
	$\Delta K/TOT$	$\Delta S/TOT$	$\Delta O/TOT$	$\Delta K/TOT$	$\Delta S/TOT$	$\Delta O/TOT$
1955	.948	.015	.037	.919	.044	.036
1960	.918	.026	.056	.868	.078	.054
1965	.946	.022	.032	.858	.111	.037
1970	.942	.022	.036	.865	.112	.023
1975	.835	.104	.060	.605	.367	.028
1980	.723	.158	.120	.493	.447	.059
1985	.576	.126	.298	.394	.441	.164
AAGR (%)	-1.65	7.35	7.20	-2.78	7.99	5.18

Note: $TOT=\Delta K+\Delta S+\Delta O$ in 1972 constant dollars

Overall, it seems that investment was not as slack in the PM industry as has been suggested, except for S-equipment, which is higher both in terms of

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[5] These expenditures, although interpreted in terms of research intensity, could provide a biased indication of this investment since most R&D investment is for labor and materials, which are not explicitly included here.

levels and rates of change throughout in the CM industry. Investment instead varied more significantly across the different assets than between the industries. Investment for plant and equipment declined somewhat in the 1980s, and especially by 1985 for both industries, but investment in high tech capital remained strong.[6]

These indicators of market conditions and investment behavior provide useful information for assessing the economic performance of firms. However, an important next step is to pursue this further to consider possible causes and effects. In particular, we may want to determine the effects of market conditions, to identify the factors underlying investment decisions, and to distinguish the resulting impact on economic performance. This requires further analysis of investment incentives, technology and decision processes, which involves computing the measures discussed in the previous section, based on the estimated parameters of the cost and demand functions (1) and (2).

IVb. Measures of Investment Incentives and Productive Performance

Indexes of the shadow value ratios ZkRAT=$Z_k/p_k{}'$ are presented in Table 4. These measures can be used to assess the economic motivation underlying differences and similarities in investment decisions across assets and between industries. In particular, we have seen that overall investment was only slightly more sluggish over time for the PM than the CM industry, and more for general than for high-tech capital. The Dertouzos <u>et al.</u> study, however, suggests that there was stagnation of investment in the PM industry due to

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[6] Investment patterns are clearly evident from this table even without information on the intervening years; when all these years are included, the trends noted strongly dominate yearly fluctuations. However, some additional interesting information may be gleaned by considering all years. In particular, in the expanded indexes the post-recession years of 1976-78 and 1983 turn out to be strong investment years for both types of high-tech capital, but the tendency is not nearly as pronounced for general capital. Also, the 1960s were years of heavy investment in K for the PM industry and the late 1970s were similarly investment-intensive for chemicals firms.

Table 4: Shadow Value Ratios

	Primary Metals			Chemicals		
Year	ZKRAT	ZSRAT	ZORAT	ZKRAT	ZSRAT	ZORAT
1955	1.669	1.402	1.763	.553	1.241	2.897
1956	1.472	1.426	2.597	.675	1.260	2.795
1957	1.137	1.298	1.525	.736	1.131	2.209
1958	1.204	.932	.998	.845	.888	1.619
1959	.943	.964	1.129	.734	1.118	1.845
1960	.892	.971	1.126	.844	1.043	1.682
1961	1.110	.984	1.172	.979	1.034	1.420
1962	1.072	1.025	1.106	1.055	1.174	1.322
1963	1.273	1.029	1.108	1.040	1.253	1.074
1964	1.435	1.108	1.255	1.171	1.297	.968
1965	1.636	1.131	1.260	1.326	1.195	.884
1966	1.156	.921	.952	1.135	1.077	.611
1967	1.232	.909	.987	1.235	.732	.468
1968	.989	.811	.714	.798	.684	.510
1969	.555	.774	.686	.484	.768	.475
1970	.834	.769	.848	.640	.865	.514
1971	.965	.793	.961	.740	.925	.449
1972	1.099	.979	1.093	.687	1.088	.630
1973	1.076	1.017	1.056	.621	1.194	.732
1974	1.609	1.216	1.526	1.035	1.219	1.052
1975	1.192	1.059	1.261	1.461	.854	1.107
1976	1.180	1.033	1.507	1.201	.890	1.269
1977	1.346	1.197	1.443	1.129	1.010	1.394
1978	.983	1.212	.988	.901	1.087	1.295
1979	1.402	1.085	1.032	1.009	1.033	1.198
1980	1.286	1.057	1.285	1.126	1.008	1.111
1981	1.199	.912	.899	.982	.995	1.065
1982	.567	.768	.551	1.022	1.010	1.020
1983	.724	.727	.717	1.024	1.008	1.055
1984	.838	.808	.943	.894	.961	1.034
1985	.775	.722	.704	1.003	.966	.975
1986	.796	.664	.232	1.079	.993	.836

demand and performance problems, whereas investment declined somewhat even with expansion and thus investment pressure in the CM industry. This implies that investment was more strongly motivated by economic factors in the CM than the PM industry.

This conclusion is essentially consistent with the shadow value ratios found for the two industries, especially at the end of the sample, although the extent of the differential in investment incentives seems overstated. The shadow value ratios for general capital tended to be larger in the post-1974 period for chemicals than for primary metals, particularly after 1981. Those for S- and O-capital, however, were often greater in the PM industry until 1981, when investment incentives increased for chemicals firms for both types of high-tech equipment, even though the ratio was often below one. This disparity is increasingly evident in the 1980s, with a very low shadow value for O investment in the PM industry for 1986 following a high investment rate in 1985.[7]

The observed investment patterns thus seem to be appropriate responses to apparent economic motivations, except possibly at the end of the period (especially for O-equipment) in primary materials and for the mid-1970s for S-equipment by CM firms.[8] In fact, more investment might have been desirable for PM firms in the late 1970s, counteracting suggestions that primary metals firms overinvested in terms of economic performance; it appears that until 1981 performance would have been even worse if investment rates were lower. The similar investment patterns across industries were therefore generally consistent with economic incentives in terms of cost savings.

[7] Although most of the patterns exhibited by these indexes were quite robust to alternative specifications, those for Z_O/p_O were more volatile. In particular, the upward swing in this ratio found for both industries did not appear in some specifications.

[8] Note that this ratio is defined in terms of current returns, so future expected returns would not be reflected here. Since S-investment might be expected to yield future returns, especially if it is research equipment, this would understate its current value.

The determinants of these shadow value patterns are useful to explore, since incentives for investment responses to economic conditions depend on the cost-effects of exogenous factors such as energy price changes. These determinants may be analyzed using elasticities with respect to changes in such factors; this is pursued briefly below. To a certain extent, however, the result of such an exercise may be indicated by the cyclical nature of the ratios. For example, shadow value ratios for physical plant and equipment fell in the PM industry in both 1975 and 1982 -- after energy price increases -- and in the later period they stayed low. This tendency does not appear for the CM industry, except possibly for S-capital. This suggests that energy prices more seriously impacted the PM than the CM industry.

The shadow value ratios also reflect utilization rates for the different fixed factors, which may be summarized for all capital assets by the capacity utilization measure $C^*/C=CU_c$. This measure can be interpreted as an overall measure of investment motivations and short term cost effects. Additional cost incentives for investment may arise from scale economies. Measures of these two components of the total cost elasticity ϵ_{CY}, representing the cost-output relationship in these industries and thus potential profitability, are presented in Table 5.

The CU_c measures reported in Table 5 indicate that utilization rates were low in the late 1960s for both industries, but then recovered, with an apparently more permanent and significant decrease for the PM industry after 1981. Some overutilization still appeared for the chemicals industry in this later period, except in 1984. Overall, however, these measures are close to one, especially for the CM industry, suggesting that short run constraints on investment did not have a strong impact on cost effectiveness in either industry.

Table 5: Capacity Utilization and Scale Economies

	Primary Metals		Chemicals	
Year	CU_c	ϵ_{CY}^{L}	CU_c	ϵ_{CY}^{L}
1955	1.076	.603	.959	1.019
1956	1.062	.609	.971	1.009
1957	1.023	.634	.971	1.003
1958	1.027	.685	.979	1.007
1959	.991	.672	.970	.975
1960	.983	.675	.981	.974
1961	1.015	.684	1.000	.967
1962	1.010	.675	1.011	.955
1963	1.030	.665	1.008	.942
1964	1.046	.649	1.021	.934
1965	1.060	.631	1.035	.929
1966	1.019	.614	1.012	.915
1967	1.028	.628	1.019	.920
1968	.996	.624	.959	.883
1969	.899	.621	.889	.854
1970	.972	.648	.937	.836
1971	.994	.652	.956	.831
1972	1.012	.628	.957	.793
1973	1.010	.594	.952	.757
1974	1.057	.593	1.007	.769
1975	1.022	.646	1.056	.828
1976	1.023	.633	1.025	.798
1977	1.038	.619	1.019	.768
1978	.999	.601	.991	.732
1979	1.040	.602	1.004	.726
1980	1.030	.636	1.020	.731
1981	1.018	.635	.998	.691
1982	.914	.693	1.004	.706
1983	.952	.683	1.005	.683
1984	.976	.674	.981	.644
1985	.961	.686	.998	.675
1986	.961	.693	1.008	.686

This utilization pattern does not support the suggestion by Dertouzos et al. of a substantial increase in utilization in the CM industry, which appeared justified from the decline in capital intensity in this industry. The evidence here instead indicates that substitution possibilities toward other inputs were expanding; CM firms seem to have simply kept utilization rates fairly constant given technological changes. This flexibility may have allowed CM firms to minimize costs more effectively than firms in the PM industry. The PM industry, by contrast, seemed less able to take advantage of substitution possibilities, and was more constrained by excessive capacity in the 1980s.

Scale economies from factors other than fixity of capital seem to be even more important for explaining trends in investment and performance. The indexes in Table 5, for example, suggest that scale effects were large but stable in the PM industry throughout the sample, with a slight decline in their effect late in the sample. This is consistent with the notion of a "technological maturity" affecting the profitability of PM firms, particularly when production increases to take advantage of existing scale economies were not possible due to demand and import conditions. However, the CM industry experienced increasingly greater scale economies during this period, causing an incentive to invest in further technology. The leveling off evident for the CM industry in the late 1970s is also consistent with stagnation during this period, that may have been attenuated by investment in R&D, as noted by Dertouzos et al..

The ϵ_{CY} elasticity reported in Table 6 combines the impacts of capital fixity and the other scale effects. These measures highlight the flat or even slightly diminishing potential for generating short and long run scale economies in the PM industry, and the increasing possibilities in the CM

Table 6: Cost Elasticity, Markup and Profitability ($\epsilon_{CY} \cdot p_Y/MC$)

	Primary Metals			Chemicals		
Year	ϵ_{CY}	p_Y/MC	PROF	ϵ_{CY}	p_Y/MC	PROF
1955	.649	1.583	1.028	.977	1.153	1.127
1956	.647	1.541	.997	.979	1.157	1.133
1957	.649	1.496	.970	.974	1.156	1.126
1958	.704	1.418	.998	.985	1.145	1.128
1959	.666	1.439	.959	.946	1.179	1.115
1960	.663	1.441	.956	.956	1.175	1.123
1961	.695	1.416	.984	.967	1.182	1.143
1962	.681	1.447	.986	.965	1.199	1.156
1963	.685	1.478	1.013	.949	1.215	1.154
1964	.679	1.507	1.023	.954	1.225	1.168
1965	.669	1.546	1.034	.962	1.242	1.194
1966	.626	1.610	1.008	.927	1.264	1.171
1967	.645	1.571	1.014	.938	1.268	1.190
1968	.621	1.600	.994	.847	1.323	1.120
1969	.558	1.633	.912	.760	1.360	1.033
1970	.630	1.542	.971	.783	1.365	1.069
1971	.648	1.507	.977	.794	1.366	1.085
1972	.635	1.570	.998	.760	1.417	1.077
1973	.599	1.681	1.007	.720	1.475	1.063
1974	.627	1.625	1.019	.775	1.402	1.087
1975	.660	1.498	.989	.874	1.286	1.123
1976	.647	1.496	.968	.818	1.325	1.084
1977	.643	1.513	.973	.783	1.367	1.070
1978	.600	1.574	.945	.726	1.415	1.027
1979	.625	1.573	.984	.729	1.414	1.031
1980	.655	1.494	.978	.746	1.372	1.023
1981	.646	1.526	.987	.689	1.394	.961
1982	.633	1.365	.865	.709	1.343	.952
1983	.650	1.357	.881	.687	1.374	.944
1984	.658	1.376	.905	.632	1.418	.897
1985	.659	1.346	.887	.674	1.385	.934
1986	.666	1.323	.881	.692	1.397	.966

industry. Combining this with the evidence about markups contained in Table 6 provides intriguing information about profitability.

Markups (p_Y/MC) for the primary metals industry have dropped over time, indicating less market power from more (international) competitiveness, reduced potential to take advantage of returns from scale economies, or possibly the effects of imposed price constraints. By contrast, chemicals companies appear to be increasingly able to markup prices over marginal cost, largely due to scale economies imbedded in the technology, but possibly also from stronger demand even with increasing imports in this industry, or expanding specialization.

As elaborated above, profitability can be measured simply as $PROF=p_Y\cdot Y/C=\epsilon_{CY}\cdot p_Y/MC$, which represents the excess of revenue over costs. The PROF measure reported in Table 6 suggests that financial performance has declined in both industries but particularly for PM, due largely to less technological potential and substitution flexibility as well as a declining ability to markup prices.

In particular, profitability dropped considerably over time in primary metals, noticeably after 1974 and dramatically after 1981, consistent with the low or negative earnings found in later years by Dertouzos et al.. The measures in Tables 5 and 6 suggest this is due to the reduced ability to markup prices given the stable technology, and the reduction in capacity utilization after 1981. Profitability was quite high for chemicals firms in the 1960s. Although it remained relatively strong, it began to fall in the late 1970s and did not effectively recover within the sample period. The markup was unable to keep up with investment and market conditions after 1981, possibly due to increased competitiveness, although improvements are apparent in 1985-1986.

Productive performance was also poor throughout the time period, particularly for the PM industry as shown by the traditionally measured productivity growth indexes (ϵ_{Ct}) in Table 7.[9] Productivity growth dropped considerably over time in the primary metals industry, and experienced precipitous declines in 1975 and 1982, but was quite strong for chemicals firms until 1973 and again after 1975 (particularly after 1980). However, this evidence is changed somewhat when the impacts of fixity and scale effects are taken into account.

When the impacts of fixity of capital (utilization) are removed from the measure (to generate $\epsilon_{Ct}{}^F$), the impact on the technical change measure is mixed for the first decade, but for both industries productivity growth appears somewhat better. This suggests that fixity constrained short run productivity growth during this period; it caused traditional productivity growth measures to be understated in terms of true technical change. This is reversed in the later years, especially for CM. For example, fixity caused productivity declines in 1974-1977 in the PM industry to be understated, although in later years productivity changes do not appear as poor once utilization is taken into account -- fixity worsened the post-1981 evidence of productivity declines. For CM, productivity growth net of fixity effects is poorer than usually measured both in the post-1973 and post-1979 period.

Further adjustment for scale (to obtain $\epsilon_{Ct}{}^T$) has an even more dramatic influence. This adjustment clearly attenuates the productivity growth upturn in the later years for the CM industry, indicating that evidence of stronger productive performance in this industry is less a technical change effect than one resulting from short and long run scale effects.[10] For the PM industry,

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[9] These indexes are presented so that a productivity increase is a positive number, even though ϵ_{Ct} represents cost diminution.

[10] Note, however, that this effect could be a result of technology embodied in new capital, so the distinction here is not completely clear. This does, however, help to identify more clearly the components of productivity to motivate interpretation and additional exploration.

Table 7: Productivity Growth (%) -- traditional and adjusted

	Primary Metals			Chemicals		
Year	ϵ_{Ct}	ϵ_{Ct}^F	ϵ_{Ct}^T	ϵ_{Ct}	ϵ_{Ct}^F	ϵ_{Ct}^T
1955	4.202	6.850	-2.629	5.714	5.581	5.923
1956	-2.578	-2.723	-2.980	1.769	2.220	2.297
1957	0.419	-1.178	1.444	2.227	1.247	1.256
1958	-7.316	-8.929	-1.636	0.230	-1.630	-1.638
1959	3.773	4.622	1.274	11.450	11.169	11.001
1960	-2.096	-1.868	-2.214	-0.424	-0.160	-0.193
1961	0.732	0.880	1.832	1.693	0.806	0.665
1962	0.198	0.624	-1.800	2.788	2.634	2.338
1963	2.191	2.580	0.525	2.780	2.760	2.420
1964	2.478	2.886	-0.141	4.104	4.023	3.590
1965	0.215	0.709	-2.412	2.252	2.289	1.731
1966	1.761	2.233	-0.879	0.696	0.788	0.208
1967	-2.018	-1.844	-0.133	-2.957	-2.699	-3.055
1968	-2.120	-1.728	-2.862	3.314	3.468	2.527
1969	-0.547	-0.468	-1.357	2.092	1.812	1.074
1970	-1.883	-1.550	1.515	2.010	1.743	1.506
1971	0.138	0.675	1.330	2.709	3.393	2.824
1972	2.014	2.161	-1.646	4.064	4.098	2.174
1973	4.551	4.488	-0.842	3.881	3.597	1.688
1974	-1.213	-1.891	-2.562	-4.344	-4.818	-4.921
1975	-10.850	-12.804	-4.438	-4.945	-5.887	-3.156
1976	-0.612	-1.091	-2.498	2.618	3.241	1.327
1977	-3.806	-4.484	-5.577	0.809	0.684	-1.162
1978	1.865	0.897	-1.932	0.024	-0.943	-2.186
1979	-0.470	-1.358	-2.117	1.910	0.895	0.243
1980	1.699	-0.203	4.149	-2.810	-4.555	-3.160
1981	2.228	0.556	-0.232	3.489	1.851	0.938
1982	-10.134	-9.419	0.929	0.072	-0.921	1.409
1983	-3.504	-1.930	-2.269	2.142	1.644	-0.482
1984	6.124	4.807	2.244	1.026	-1.216	-2.766
1985	-0.776	-0.280	1.899	-1.068	-4.292	-3.427
1986	-1.480	-0.144	1.364	4.845	-1.460	-2.663

however, it appears from the adjusted measures that the technical change downturn has been overstated; when scale economies are taken into account the remaining measure of technical change is negative from 1972 to 1979, but then recovers more effectively than in the CM industry.

In sum, the productivity growth decline experienced in the PM industry may to a large extent be attributed to fixity and scale effects in tandem with reductions in production, whereas some of the growth found for the CM industry is due to scale economies given expansions of production rather than to technical change. The observed apparent productivity "turnaround" in financial and productive performance for chemicals firms can thus be attributed at least in part to scale economies and overutilization of capital supporting larger markups.

IVc. Elasticities of Investment and Performance Measures

Finally, it is useful to explore the determinants of some of these measures to assess what has caused changes in the measures of investment incentives and performance overviewed in this section. This can be pursued using the elasticity estimates presented in Tables 8 and 9 for the PM and CM industries, respectively. To facilitate comparisons across time, these elasticities are presented for 1965 and 1985 .[11] Also, computations for both direct (allowing for no adjustment of output) and indirect (incorporating output production changes and their effects) responses are reported. The latter distinction can be thought of as reflecting the difference between a cost-minimization as compared to a profit maximization response.

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[11] It should be noted that the elasticity computations do not tend to be volatile, so these comparisons are quite representative. Elasticities that appear to be relatively volatile across time include the direct elasticity of S capital with respect to changes in O, and the indirect elasticities of the markup with respect to p_L, Z_S with respect to p_L, and O with respect to both K and S (the responsiveness to K is reversed to that for S).

Table 8: Primary Metals Industry Elasticities

	ZKRAT		ZSRAT		ZORAT		ϵ_{CY}		P_Y/MC	
EXOG	1965	1985	1965	1985	1965	1985	1965	1985	1965	1985
DIRECT										
P_E	.599	1.248	-.036	.551	-.696	-.621	.036	.155	-.011	-.020
P_M	.157	.060	.693	.649	5.647	.385	.067	.052	-.225	-.172
P_L	.225	.192	.381	.519	-4.017	1.012	-.006	.044	-.117	-.065
K	-.453	-.413	.044	-.004	.165	-1.813	-.094	-.173	.054	.033
S	-.213	-.884	-.053	.528	-.064	-1.011	-.025	-.153	.002	.001
O	.087	.290	-.328	-.616	-.669	-1.928	-.0004	.023	.004	.007
Y	.588	1.549	-.264	-.306	-.769	3.798	-.340	.007	.364	.274
t	.187	.458	.049	1.240	2.244	1.628	.118	.173	-.078	-.075
IMPRAT									-.019	-.024
UN									.034	.033
EXP									.248	.190
P_I									.020	.016
CPI									.019	.014
INDIRECT										
P_E	.645	1.762	-.057	.617	-.757	.639	.009	.157	-.006	-.021
P_M	1.092	4.474	.274	1.210	4.424	11.208	-.474	.072	-.129	-.177
P_L	.719	1.869	.162	.732	-4.655	5.124	-.289	.052	-.067	-.067
K	-.677	-1.271	.145	-.113	.459	-3.918	.037	-.177	.031	.034
S	-.220	-.916	-.049	.524	-.055	-1.090	-.021	-.153	.0009	.001
O	.071	.117	-.321	-.638	-.648	-2.353	.009	.023	.002	.007
Y	.588	1.549	-.264	.197	-.769	3.798	-.340	.007	.319	.173
t	.037	.068	-.008	.012	.118	.182	-.006	.005	-.003	-.002
IMPRAT	-.044	-.215	.020	-.027	.058	-.527	.026	-.001	-.058	-.092
UN	.076	.290	-.034	.037	-.100	.712	-.044	.001	.100	.124
EXP	.563	1.686	-.252	.214	-.736	4.133	-.326	.007	.949	.989
P_I	.047	.139	-.021	.018	-.067	.341	-.027	-.001	.079	.082
CPI	.043	.121	-.019	.015	-.063	.297	-.025	-.001	.073	.071

Table 9: Chemicals Industry Elasticities

	ZKRAT		ZSRAT		ZORAT		ϵ_{CY}		p_Y/MC	
EXOG	1965	1985	1965	1985	1965	1985	1965	1985	1965	1985
DIRECT										
p_E	.023	.467	.515	.997	.988	.779	-.016	-.045	-.005	.010
p_M	2.377	1.355	-1.544	-1.255	.911	.193	.425	.602	-.173	-.323
p_L	-1.444	-1.009	2.047	1.237	-1.226	-.853	-.293	-.373	-.017	-.014
K	.294	.102	-1.789	-1.156	-1.366	-.909	.219	.329	-.035	-.088
S	-.171	-.273	-.157	.070	.184	.307	-.020	-.041	.004	.013
O	-.207	-.471	.046	-.255	-.383	-.381	-.027	-.103	.003	.007
Y	-1.373	2.291	1.483	.266	1.851	.643	-.415	-1.176	.224	.552
t	-1.739	3.348	-1.339	-1.746	-1.498	-1.779	.286	.726	-.013	-.240
IMPRAT									-.005	-.012
UN									-.019	-.031
EXP									-.036	-.056
p_I									.019	.029
CPI									.206	.298
INDIRECT										
p_E	-.098	.423	.662	.969	.779	.090	-.054	-.009	-.003	.002
p_M	-2.063	-.252	3.415	-.980	4.730	.096	-.947	-.524	-.094	-.052
p_L	-1.803	-.712	2.571	1.192	-.423	-.108	-.427	-.284	-.009	.004
K	-.593	-.299	-.815	-1.062	-.089	-.088	-.058	.011	-.019	-.015
S	-.053	-.165	-.287	.058	.019	.034	.015	.007	.002	.002
O	-.129	-.352	-.033	-.255	-.324	-.047	-.005	-.077	.002	.001
Y	-1.312	-1.414	1.510	.261	1.246	.077	-.415	-1.176	.241	1.122
t	.124	.048	-.065	-.043	-.046	-.004	.012	-.004	-.0005	-.001
IMPRAT	.032	.020	-.037	-.004	-.031	-.001	.010	.017	-.024	-.046
UN	.112	.052	-.129	-.009	-.107	-.003	.036	.043	-.086	-.115
EXP	.218	.093	-.251	-.017	-.207	-.005	.069	.077	-.229	-.274
p_I	-.115	-1.248	.132	.009	.109	.003	-.036	-.040	.121	.144
CPI	-.049	-.496	1.436	.091	1.185	.027	-.395	-.386	1.310	1.465

Although these sets of elasticities contain more information that can be summarized within the scope of this paper, some general trends can be noted. First, the signs of the elasticities are generally the same across periods. The main differences in the CM industry across time are for the elasticities of S capital. The motivations for investment in S capital have thus tended to change over the sample period, consistent with evidence of differing research intensities over time in the CM industry. The S elasticities are also volatile in the PM industry, especially when output responses are included, as well as for the O-and ϵ_{CY}-elasticities. Cost determinants in the PM industry, in terms of both scale economies and high tech capital investment incentives, have thus changed noticeably over the two-decade period 1965-85.

In terms of magnitudes for these elasticities, the tendency is for exogenous changes to have less impact on costs and investment incentives in 1985 than in 1965, and the difference between the indirect and direct responses is mixed. Also, it might be noted that the small values for indirect elasticities for S and O in the latter part of the sample for CM suggest little responsiveness of O-investment to any exogenous change facing the firm, by contrast to those for the PM industry (especially for O-capital).

More to the point, in addition to noting these general trends, one potentially illuminating exercise allowed by these elasticities is to trace through the impacts of particular exogenous "shocks". For example, shocks which have been hypothesized to be important in the above discussion and in the literature on economic performance are increasing import competitiveness (a demand shock), and energy price changes (a supply or cost shock). The impacts of such changes can be assessed by considering the pattern of elasticities with respect to changes in these factors facing the firm.

For example, if we are interested in the impact of increasing import intensity on investment and economic performance (cost and pricing changes), we can consider the IMPRAT elasticities. Increases in IMPRAT have no direct effects on the shadow value ratios and ϵ_{CY} since these cost measures are not affected by demand shocks except through changes in output production. These changes do, however, directly cause a decline in the markup both earlier and later in the sample, with the impact increasing over time and larger for the PM than the CM industry. Therefore, particularly given the much more dramatic increase in imports for the PM industry, this clearly would have a large impact on financial performance in this industry.

The indirect effects when output adjustment is included are to increase the investment incentive for K (increase ZKRAT), but to decrease it for the S and O capital components in the CM industry; increasing competitiveness causes declines in high-tech capital investment, particularly relative to general capital. In addition, this causes increases in ϵ_{CY} and more precipitous declines in the markup, suggesting a reduction in the potential to take advantage of scale economies, and to markup prices, resulting in less profitability. The pattern is similar for PM in terms of the cost and markup elasticities, except even more dramatic. The investment incentives are quite different, however; increasing the import share reduces the incentives to invest in all capital stocks later in the sample, particularly for O-capital, although earlier in the sample it motivated investment in high-tech capital.

For an energy price increase, the overall response in terms of investment incentives is to increase the shadow value ratio for the capital stocks for the CM industry, and for general capital in the PM industry, with this effect becoming stronger over time. This apparently perverse result, that appears particularly strong for O capital in the CM industry, is consistent with the general evidence of expanding capital investment in manufacturing after 1973 (as documented by researchers such as Baily and

Hulten [1990]). For the PM industry, however, this appears not to be the case for O-capital, at least in the earlier period.

The cost elasticity declines somewhat for the CM industry but rises in primary metals with an increase in energy prices, implying some combination of decreasing utilization or increased potential scale economies for CM and the reverse for PM. The markup tends to decline, suggesting that marginal costs increase more than can be adapted for by increasing prices, although in the later period this is not the case for the CM industry; firms appear to accommodate effectively through substitution. The combined impact of the cost and pricing effects of energy price increases thus appears to be more harmful to financial performance to the PM than the CM industry, both because the markup decline is smaller (or increases are possible) and because the scale effect is positive for CM.

The trends over time are also interesting to note. In addition to the enhanced potential for markups in 1985, the increases in the shadow value ratios for capital tend to be greater in the CM industry, implying that innovation might be increasingly important. A comparison of S- and O-elasticities between industries also yields interesting implications. The valuations of both S- and O- capital in the PM industry decline in the earlier period with energy price changes, whereas they increase in the CM industry, suggesting more substitution incentives for high-tech capital in chemicals firms. Although the negative impact on Z_S and Z_O is lost in the PM industry later in the sample, possibly due to more effective adjustment of capital stocks during the 1970s, the investment incentives are still not as large as for chemicals firms.[12]

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[12] Note that some of this seems due to output changes; allowing for output changes reduces the responsiveness of the Z_O ratio dramatically for the CM industry, especially in the latter part of the sample, and the reverse is the case for primary metals.

Both import competitiveness and energy prices therefore appear to have had a negative impact on the economic performance of these industries, and particularly for the PM industry. This is due at least in part to the notable differences between the industries in the impact of these factors; profitability and especially investment incentives are not as dramatically reduced on the margin by such exogenous "shocks" in the CM industry. It is even more evident for the primary metals industry, however, since increases in the proportion of demand supplied by imports has been much more dramatic and capital intensity has become greater.

A last type of impact to consider is that of investment on the cost elasticity with respect to output and markups. This provides useful information on the cost effects of investment in different capital assets -- for example the impact of O on ϵ_{CY}. A glance at Tables 8 and 9 show that this elasticity tends to be positive for the PM industry and negative for the CM industry; adding to the stock of office and communications equipment seems to be associated with increasing (decreasing) scale effects in the CM (PM) industry. This would suggest incentives for investment in O for the CM but not the PM industry. This is counterracted, however, by evidence for the markup; the potential to markup price over marginal cost appears not only to increase, but to be somewhat larger in the PM than the CM industry and to be rising over time. The reverse pattern appears for S-investment; heavy investment in S in the CM industry seems motivated more by the ability to markup prices than to affect scale economies.

V. A Summary of the Approach and Findings

This paper has investigated linkages between investment patterns and economic performance, using a production theory framework which facilitates the quantitative analysis of patterns that have been observed or postulated using more case-study oriented methods. Based on this model, the responsiveness of investment behavior to economic factors across assets has been examined for the primary metals (PM) and chemicals (CM) industries. This analysis has focused on the valuation of different assets and resulting utilization and pricing behavior, as well as on associated technological factors such as scale economies. The impacts of such behavioral and production characteristics on financial and productive performance have been evaluated, and their determinants assessed.

Although evidence about investment incentives and the impact of investment on economic performance is not directly accessible from the data, the structural framework has allowed us to postulate reasons behind variations in the composition of investment and its relationship to financial and productive performance. For example, major differences in import competitiveness and some differences in capital intensity, such as an increasing (decreasing) capital intensity in general for PM (CM), and a greater S-intensity in CM were found. Nevertheless, strong similarities between investment patterns in the primary metals and chemicals industries were evident. Using parametric measures summarizing investment motivations and economic performance has, however, allowed us to identify important differences across industries in terms of the causes and results of investment behavior.

The relative valuation of most assets in the CM industry was high compared to those in primary metals firms given the existing capital stocks, especially at the end of the sample. Over time, however, declines in shadow values were seen for both industries, especially for the PM industry and for office and communications (O) equipment. Increasing scale economies were also evident for CM, which, combined with less extensive import competition, allowed larger markups. By contrast, the more "mature technology" in the PM industry caused potential scale economies to stay "flat" rather than to increase. Both industries appeared to be affected by fixities, but neither had utilization ratios dramatically different from one overall. The PM industry, however, utilized capacity less heavily later in the sample period; fixity was more of a constraint on cost minimization.

These results are generally consistent with the evidence and hypotheses provided by researchers such as Dertouzos et al.. However, using the more structural framework developed here allowed some relationships to be identified which refine or even counteract their conclusions. For example, analyzing shadow values supports the notion that large investments in O-capital in the PM industry in the mid-1980s seems to have been less than optimal in terms of cost savings in this industry, although they were more appropriate in the CM industry. However, evidence from data analysis that investment was too high in the PM industry in the late 1970s appears somewhat erroneous; performance would have been even worse with lower investment before 1981. In addition, lower investment in S-equipment in this industry seems economically motivated rather than an indication of mismanagement. These values also indicate that utilization did not increase in the CM industry as has been suggested; instead, utilization seems quite constant due to increased flexibility from expanding opportunitites for substitution over this period, particularly relative to the PM industry.

Elasticities of these measures indicate that low shadow values of O-equipment in this industry tended to result from increases in the prices of energy and labor and expanding import competition (especially later in the sample). Elasticities of scale effects and markups also suggest that the investments in O-capital allow markups to increase in both industries somewhat, but cause scale economies to be reduced in the PM industry.

In sum, the "technological maturity", high capital-intensity and more imports that characterize the PM industry appear to be associated with worsened financial performance, due to the reduced ability to take advantage of scale economies, greater cost-impacts of fixities and energy prices, less incentives to invest in high-tech capital, and the diminished potential for markup behavior. However, in terms of productive performance I have also been able to show that due to utilization variations and the existence of scale economies, productivity performance measures have tended to be biased downward in the primary metals industry and upward in the chemicals industry.

VI. References

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