INVESTMENT IN MANUFACTURING, EXCHANGE-RATES AND EXTERNAL EXPOSURE

BY

Jose Campa
and
Linda S. Goldberg

RR # 93-18 *April, 1993*

C. V. STARR CENTER FOR APPLIED ECONOMICS

NEW YORK UNIVERSITY
FACULTY OF ARTS AND SCIENCE
DEPARTMENT OF ECONOMICS
WASHINGTON SQUARE
NEW YORK, N.Y. 10003

Investment in Manufacturing, Exchange-Rates and External Exposure

(April 19,1993)

ABSTRACT

This paper studies the linkage between exchange rates and investment, emphasizing the role of producer exposure through export sales and through imported inputs into production. For two-digit United States manufacturing sectors we present time series of export shares and imported input shares. On average, manufacturing sectors have evolved from being primarily export exposed in the 1970s to being primarily import exposed by the early 1980s. Due to this pattern in exposure, exchange rate appreciations reduced investment in durable goods sectors in the 1970s and stimulated investment after 1983. By contrast nondurables sectors tended to absorb exchange rate changes in price over cost markups. Exchange rate volatility depressed investment but the effects were quantitatively small.

Jose Campa
New York University
Stern School of Business
44 West 4th Street
New York, N.Y. 10012
212-998-0429

Linda S. Goldberg
New York University and NBER
Department of Economics
269 Mercer Street
New York, N.Y. 10003
212-998-8938

I. INTRODUCTION[1]

Exchange rate changes, by effecting expected industry profitability, also effect the pattern and scale of investment in United States industries. In this paper, we consider the empirical relevance of this assertion, concentrating on the impact of both exchange rate changes and the volatility of the exchange rate process, as well as on the channels through which these exchange rate effects are manifested. After specifying a simple relationship between exchange rates and profitability, wherein exchange rates matter both for export sales and imported inputs into production, and the relationship between expected profitability and investment, we turn to an empirical analysis of investment in 20 two-digit SIC manufacturing sectors.

The empirical analysis performs two objectives. First, it examines the time pattern of export and imported input exposure of United States manufacturing sectors. Instead of the standard treatment of import exposure, which measures the extent of import concentration within the industry, we focus on the industry utilization of imported inputs into production. Our imported input exposure series are constructed starting from the input-output tables for each of these two digit industries. The net exposures of the 20 two-digit industries are traced for the period between 1972 and 1986.

The second objective of the empirical analysis is to examine the importance of the export exposure, import exposure, and net exposure channels for the transmission of exchange rate activity into real domestic investment. We estimate interacted regressions to study and compare the responsiveness of investment in two digit industries to exchange rate levels and exchange rate volatility. The interacted regression approach is used in response to a common feature of the existing empirical studies of the linkages between exchange rates and real activity. Therein sectoral responsiveness is assumed stable and

[1]Linda Goldberg is grateful for the research support provided by a grant from the C.V. Starr Center of Applied Economics and by the National Science Foundation. The authors appreciate the research assistance of Jian Yao and the useful comments provided by Charles Himmelberg.

constant over time.[2] But this approach has a potential weakness noted by Goldberg (1991), who found that the effects of exchange rate changes on United States investment differed across a sample split between the 1970s and 1980s. The interacted regression approach enables us to show how and why the effects of exchange rates on manufacturing investment have changed dramatically over the 1970s and the 1980s.

In Section II we use a simple theoretical model to demonstrate that the response of sectoral investment to exchange rates depends on the evolving scale and type of industry exposure to exchange rate shocks. In most discussions of industry exposure to exchange ratesexport markets are highlighted, as in Lipsey (1988), Dixit (1989), and Baldwin and Krugman (1989).[3] However, we emphasize that exposure to exchange rate risk works through dependence on imported inputs into production as well as through dependence on revenues from export markets.[4]

In Section III we provide sectoral time series on the external exposure of sectors both through the imported input and the export share channels. Most United States manufacturing industries have considerably increased their external exposure over the last two decades. This external exposure has risen more through increased reliance on imported inputs into production, rather than through increasing export to shipment ratios in the sectors. Despite this phenomenon, the differential effects of exposure through these respective channels is neglected in the literature.

In Section IV our annual exposure indices are used to determine the effects of exchange rate levels and exchange rate volatility on investment in United States manufacturing. The interacted regressions are estimated over pooled groups of twenty two-digit manufacturing sectors, wherein the pooling occurs over the complete sample

[2]See Jorion (1990) and Luchrman (1991) for analysis of stock reactions to exchange rate changes.
[3]Other effects on domestic investment can work through international wealth effects in competing for domestic investment, as in Froot and Stein (1991).
[4]Ungern-Sternberg and Weizacker (1990) also stress that differences across industry structures are important determinants of a firm's net exposure to exchange rates.

and separately over durables and nondurables manufacturing sectors. The sectoral implications of exchange rate movements for investment strongly depend on the external exposure of the producers. Moreover, the form of exposure is very important for the significance of these linkages: the higher the exposure to imported inputs, the more that domestic currency depreciation depressed domestic investment; the higher the export share of the industry, the more domestic currency depreciation stimulated investment.

When the durable and nondurable goods sectors are examined separately, we observe that investments in the nondurable sectors were much less responsive to movements in exchange rates than were investments in manufacturing durables sectors. By analyzing the behavior of sectoral price over cost markups, we conclude that nondurables producers absorb exchange rate changes in their price over cost mark-ups so that profits are less affected by exchange rates.

In addition to focusing on the real effects of changes in exchange rate levels, we also address the unresolved theoretical and empirical issue of whether exchange rate variability *per se* matters for real investment activity. It often is argued that variable exchange rates, by creating an uncertain economic environment, depress investment and other forms of real economic activity. By contrast, according to production flexibility arguments, exchange rate variability may actually serve to stimulate domestic investment, as in de Meza and van der Ploeg (1987) and Aizenman (1992).[5] The empirical literature on the link between exchange rate variability and real economic activity, such as production and investment, is sparse.[6] Goldberg (1991), using quarterly data, concluded

[5]In general, the theoretical linkages between exchange-rate variability and domestic and foreign investment are subsumed within one of two arguments: i) utility, in the context of uncertain expected profits, is reduced when producer/investors are risk averse. Investment may be depressed when the producer uses an *ex ante* decision over the location of its production facilities to minimize the potential variability of his profits; or, alternatively, ii) due to the advantages of having *ex post* production flexibility, *ex ante* there is increased or even over-investment in capacity of production. This discussion is related to the literature on uncertainty and investment irreversibilities, as in Hartman (1972), Abel (1983), Pindyck (1988) and Caballero (1991).

[6]For a recent analysis of the link between exchange rate variability and exports see Klein (1990).

that exchange-rate variability tended to depress investment in sectors of United States industry in both the 1970s and the 1980s, but uncertainty was associated with more pronounced negative effects in the 1980s. Bell and Campa (1991), in studying the chemical processing industry, concluded that exchange rate variability also decreased investment in a sample of European countries. Goldberg and Kolstad (1993) showed that although there is a restrictive set of conditions which must be satisfied for short term exchange rate variability to influence foreign direct investment (FDI) activity: nonetheless increased exchange rate volatility tends to stimulate US bilateral FDI flows.

Our analysis shows that the effects of exchange rate variability on investment, while associated with the type and degree of external exposure of the sector, are quantitatively small. Exchange rate variability depresses investment mainly in the durable goods sectors. These effects of uncertainty, all derived using annual data, are consistent with arguments about the risk averse behavior of producer/investors, but are not supportive of production flexibility arguments.

II. A Simple Model of Investment, Exchange Rates, and External Exposure

This section presents a model of the intertemporal decision making of a producer to demonstrate a linkage between domestic investment, import and export dependence, and the behavior of real exchange rates. The investment decision in an industry indexed by i with output, y_i, sold both in home markets and abroad, takes the form:[7]

$$I^i = \phi\left(E\left(\pi^i\left(e, p_i, p_i^*, w, w^*\right)\right), r\right) \tag{1}$$

[7]Time subscripts are implicit in the equation but are dropped for expositional convenience. The basic model presented here emphasizes the static rather than dynamic motives for investment, and does not explicitly discuss the optimal timing of investment when investment is irreversible and lumpy. Since our arguments will extend to these more complex approaches, we maintain the basic model for heuristic purposes. Within the basic model, one could also directly introduce the expected volatility of profits, as in Wolak and Kolstad (1991). This analysis is provided in Appendix 1. We do not address the role of exchange-rate levels and exchange rate variability in the optimal location choice of production facilities as in Aizenman (1992) and Goldberg and Kolstad (1993).

so that investment by industry i, I^i, is a general function of the expected profits of the industry $E(\pi^i)$ and the return r on alternative investment opportunities. e denotes the real exchange rate, defined in terms of domestic currency per unit of foreign exchange. p_i and p_i^* denote the real price of good i in domestic and foreign markets, and w and w^* are domestic and foreign wage costs, respectively.

Production relies both on imported production inputs, with each unit of foreign costs w^* converted into domestic currency value using the exchange rate, and on domestically-produced inputs (including labor), with unit input costs w. Domestic demand is denoted by q_i and foreign demand is denoted by q_i^*. The production technology is assumed fixed through the entire sample (in our empirical analysis this will be the technology drawn from the US 1982 input-output tables of industry), although there is substitutability across factors of production in an industry.

To analyze the effect on investment of movements in the exchange rate and movements in exchange rate volatility we differentiate this investment equation:

$$dI^i = \phi_1 \frac{dE(\pi^i)}{d\mu} d\mu + \phi_1 \frac{dE(\pi^i)}{d\sigma^2} d\sigma^2 + \phi_2 dr \tag{2}$$

where ϕ_i represents the partial derivative of ϕ with respect to the i^th^ argument.

Following most of the literature, we assume that the exchange rate is a log-normally distributed variable, where the log-normal distribution has mean μ and standard deviation σ. In our context it is assumed that the individual firm does not have any recognizable ability to influence either the exchange rate levels, exchange rate volatility or interest rates, all of which are viewed as exogenously given.

To compute the effect of changes in the exchange rate on expected profits, we first specify per period profits for a representative firm in industry i as:

$$\pi^i = p_i(\hat{q}_i)\cdot\hat{q}_i + ep_i^*(\hat{q}_i^*)\cdot\hat{q}_i^* - c_i(w, e, w^*, \hat{y}_i) \quad \text{with } \hat{q}_i, \hat{q}_i^* \geq 0 \tag{3}$$

where a "^" over a variable denotes the optimal values obtained from the corresponding maximization problem. $p_i(q_i)$ and $p_i^*(q_i^*)$ are the domestic and foreign demand curves facing the firm. $c_i(w,e,w^*)\hat{y}_i$ is the total cost of producing the aggregated volume y, where $y_i = q_i + q_i^*$.

Suppose the firm applies a constant-returns to scale production technology, with production occurring domestically but using both domestic and imported inputs:

$$y_i = (k^*)^{\alpha_i}(k)^{1-\alpha_i} \tag{4}$$

and the unit cost function is given by:

$$c_i(w,e,w^*;y_i) = A_i w^{1-\alpha_i}(ew^*)^{\alpha_i} y_i \quad \text{where } A_i = (1-\alpha_i)^{\alpha_i}\alpha_i^{-\alpha_i} \tag{5}$$

where w and ew^* are the home-currency valued input prices of k and k^* respectively. α_i denotes the share of imported inputs in total costs. Labor inputs are assumed to be domestically supplied and therefore subsumed within $1-\alpha_i$. Hereafter, foreign input costs w^* are normalized to equal 1.

As specified, the only source of uncertainty is due to movements in the real exchange rate, e. Thus,

$$E(\pi^i) = p_i(q_i)q_i + E(e)p_i^*(q_i^*)q_i^* - E(e^{\alpha_i})\cdot w^{1-\alpha_i}(q_i + q_i^*) \tag{6}$$

The value of the expected profits under lognormally distributed exchange rates is shown in Appendix 1. The direct effects on expected profits of changing the mean and standard deviation of the exchange rate process, normalized by levels of total revenues TR in the industry, are given by:

$$\frac{\partial E(\pi^i)}{\partial \mu} \Big/ TR_i = \chi_i - \varphi_i \alpha_i \tag{7}$$

where α_i is the imported input share, χ_i is the share of export revenues in total revenues, and φ_i is defined as the ratio of expected costs to expected revenues.[8] Denoting the industry price over cost markup ratio as PCM_i then $\varphi_i = \frac{1}{1+PCM_i}$. φ_i=1 depicts a perfectly competitive market, whereas φ_i approaching zero reflects a highly monopolistic industry.

By equation (7), the response of expected profits to the mean of the exchange rate depends on: (i) the export share of total sales in industry i; and (ii) the share of imported inputs in total costs, weighted by the industry mark-up ratio. As expected, the export share of total revenues has a positive sign: home currency devaluation improves the external competitive position of the home industry, to the extent that this producer sells to foreign markets. On the other hand, for a given export share, a devaluation of the home currency hurts relatively more those industries with a higher share of imported inputs. This damage is greatest in industries with a low profit margin (or alternatively stated, with a high φ_i). This second term is what we call the import exposure to exchange rate changes. The overall effect of exchange rates on profits depends on the relative export and import exposure of each industry to exchange rates. The larger the net export exposure, the higher the increase in relative profitability of that industry resulting from a depreciation of the exchange rate. Therefore, we should expect an increase in investment in that industry.

The expected profitability of the industry also responds to a change in the variance of the exchange rate process. This response, normalized by levels of total revenues in the industry, is given by:

$$\frac{\partial E(\pi^i)}{\partial \sigma^2} \Big/ TR_i = \frac{1}{2}\left(\chi_i - \varphi_i \alpha_i^{\,2}\right) \tag{8}$$

---

[8] $\chi_i = \frac{P_i^*(q_i^*)\cdot q_i^* E(e)}{P_i(q_i)\cdot q_i + P_i^*(q_i^*)\cdot q_i^* E(e)}$ and $\varphi_i = \frac{w^{1-\alpha_i}(q_i + q_i^*)E(e^{\alpha_i})}{P_i(q_i)\cdot q_i + P_i^*(q_i^*)\cdot q_i^* E(e)}$.

Changes in exchange rate variability increase expected profits through the export channel and depress expected profits if there is a high reliance on imported inputs. The net effect of exchange rate variability depends on the balance of these forces and on the competitive structure of the industry. The more competitive the industry, the more that imported input dependence dampens (or reverses) the increase in expected profits associated with increased exchange rate variability.

In this section, we have presented a simple model that illustrates the links between the statistical distribution of exchange rates and the investment activity within an industry. To translate this theory into empirical analysis, we first require details of import and export exposure of industries, in addition to information on the evolution over time of industry mark-up ratios. In Section III we construct and analyze the import and export exposure measures for a range of two-digit sectors of United States industry. This is followed by constructed industry price over cost markup ratios. In Section IV we test the model.

III. THE INDEX OF EFFECTIVE EXPOSURE

The purpose of the *Index of Effective Exposure* (IEE) of a sector or a commodity is to measure the exposure of that sector to exchange rates, both through reliance on imported inputs into production and through sales to external markets.[9] For construction of this index we begin with the 1982 Input-Output (I-O) Tables for United States Industry as compiled by the U.S. Department of Commerce. We then aggregate from the original 6 digit input output manufacturing classification (from the I-O tables) to the 2-digit SIC classification.[10] This data is combined with data on import and export shares, by sector, according to the following formula:

---

[9]Goldberg (1990) provides a more extensive discussion of this index.
[10]For the aggregation methodology, refer to Appendix A of the publication of the I-O data for 1982 in the *Survey of Current Business*, July 1991.

$$IEE_t^i = \chi_t^i - \frac{\sum_{j=1}^{n-1} m_t^j p_{82}^j q_{j,82}^i}{\sum_{j=1}^{n-1} p_{82}^j q_{j,82}^i + p_t^n q_{n,t}^i} = \chi_t^i - \alpha_t^i \tag{9}$$

where i = index representing the output sector;

j = index representing the production input sector. Out of the n possible input types, the first n-1 types correspond to manufacturing and service inputs; the n^{th} input into production is labor, assumed to be supplied domestically.

χ^i_t = share of exports in total sales of commodity i in period t.

m^j_t = share of imports in domestic consumption of commodity j in period t.

$p_t^j q_{j,t}^i$ = the value of resources from industry j that was used in production of commodity i in period t, defined for j=1,...n-1.

$p_t^n q_{n,t}^i$ = annual wage bill in real 1982 dollars in industry i in period t.

The imported input share in an industry is approximated by the second term in the IEE derivation. The ratio of exports to total production is proxied by χ_t^i.[11] The overall index is constructed using annual data for the period between 1972 and 1986. When there are no imported inputs into production the IEE^i is identical to the conventional export-to-production ratio. When IEE^i is zero, either there is zero export and zero import dependence in this industry, or the dependencies precisely offset each other.

The IEE^i provides a measure of the pattern of net exposure of 20 sectors of durable and nondurable goods manufacturing in United States industry. For 1982, Table 1 presents sample data on ratios of imports to new supply, exports to shipments, and the IEE^i construction by sector. The ratios of imports to new supply are included in the table to emphasize that shares of intra-industry trade often differ quite remarkably from shares of imported inputs into production.

[11]The Export to Shipment and Import to New Supply data are from the US Department of Commerce.

Table 1 **External Exposure of Two-Digit SIC Manufacturing Sectors: 1982**
(in percentage terms)

SIC Code	Industry Name	Imports/ New Supply	Imported Input Share	Exports/ Shipments	IEE
	Manufacturing Durables				
32	Stone, Clay and Glass	5.32	5.23	4.33	-0.90
33	Primary Metal Products	14.68	11.50	5.04	-6.46
34	Fabricated Metal Products	4.29	10.65	6.63	-4.02
35	Nonelectrical Machinery	8.43	9.01	23.29	14.28
36	Electrical Machinery	12.4	9.55	12.7	3.15
37	Transportation Equipment	15.43	11.20	15.64	4.44
38	Instruments and Related Products	10.09	8.30	17.43	9.13
39	Miscellaneous Manufacturing	24.05	10.14	9.52	-0.62
	Manufacturing Nondurables				
20	Food and Kindred Products	3.62	3.95	4.27	0.32
21	Tobacco Manufactures	1.79	2.64	10.34	7.70
22	Textile Mill Products	5.36	5.07	4.89	-0.18
23	Apparel and Other Mill Products	14.28	4.55	2.43	-2.12
24	Lumber and Wood Products	8.22	5.37	7.17	1.80
25	Furniture and Fixtures	5.25	7.45	2.47	-4.98
26	Paper and Allied Products	6.05	5.88	5.46	-0.42
27	Printing and Publishing	0.87	4.59	1.72	-2.87
28	Chemicals and Allied Products	4.54	4.76	12.53	7.77
29	Petroleum and Coal Products	7.25	6.58	3.2	-3.38
30	Rubber and Plastics Products	5.08	5.15	4.79	-0.36
31	Leather and Leather Products	33.89	15.94	5.67	-10.27

The sectors most heavily dependent on exports are nonelectrical machinery (23.3 percent of shipments are exports), instruments and related products, transportation equipment, and chemicals and allied products. The sectors relying most on imported inputs into production (in percentage terms) are leather and leather products (at 15.94 percent), followed by a group of manufacturing durables sectors with imported input ratios of approximately 11 percent, including primary metal products, transportation equipment, and fabricated metal products. Manufacturing durable sectors, as a group, have a significantly higher reliance on imported inputs into production as compared with manufacturing nondurables sectors.

When the import and export reliance of these sectors are together examined via the sectoral IEE^i measures, in 1982 the large net exporters were nonelectrical machinery, instruments and related products, chemicals and allied products, and tobacco manufactures. The large net importers are leather and leather products, and primary metal products. The ranking of sectors by IEE^i and α_t^i contrast sharply: a Spearman's rank correlation test rejects the null of equal rankings. However, a Spearman's rank correlation test cannot reject the null of equal rankings between IEE^i and χ_t^i.

Table 2	Evolution of Net Importer and Exporter Positions: Summary			
	Net Importers (based on IEE)		Net Exporters (based on IEE)	
	number	average IEE	number	average IEE
1972	13	-2.64	7	3.98
1977	10	-3.15	10	4.47
1982	12	-3.05	8	6.07
1986	16	-5.41	4	5.89

The evolution of net import and export exposure over our sample period, i.e. between 1972 and 1986, is summarized in Table 2 and graphed by sector in Appendix 2. Even in the 1970s net import exposure was more prevalent among sectors than was net export exposure. This pattern became more pronounced by the middle of the 1980s, when most sectors of United States manufacturing industries, even those with relatively high export shares, were predominantly exposed to the international economy through their use of imported inputs into production rather that through their use of export markets for their products. In 1982 twelve of the twenty 2-digit SIC sectors had negative values of IEE suggesting that these industries were net importers. By contrast, only eight 2-digit SIC sectors had positive values of IEE, suggesting that they be classified as net exporters in 1982. These results suggest that the sectoral implications of real exchange rate movements and exchange rate variability also may have changed significantly over time. Thus, given the results of our theoretical exposition, empirical analyses of the implications of exchange rate changes (see Section IV) should adjust for the altered exposure of industries.

Equations (7) and (8) also showed that the impact of exchange rates on investment will be determined by the competitive structure of the industry, which in turn is captured by the price over cost mark-up in the industry. As demonstrated by Domowitz, Hubbard and Petersen [DHP] (1986), it is important to recognize the time-varying nature of these margins, and to account for the behavior of the value of sales and changes in inventories, instead of measuring output exclusively as, for example, in the work by Hall (1988). Following the DHP methodology, we construct price cost margins for the 1972 to 1986 interval using the following measure:

$$PCM = \frac{\text{value of sales } + \Delta\text{inventories } - \text{ payroll } - \text{cost of materials}}{\text{value of sales } + \Delta\text{inventories}} \tag{10}$$

which is identical to (value added - payroll)/(value added + cost of materials), given the Census' definition of value added. The latter is what we have computed using data drawn from the *Census of Manufactures* and from the *Annual Survey of Manufactures*, both published by the United States Bureau of the Census.

The resulting mark-up ratios, shown for a subset of the years of our complete sample, are provided in Table 3. DHP concluded that some of these mark-up ratios vary considerably over time for the period between 1950 and 1981, with a narrowing over time of the spread of price-cost margins with respect to concentration due in part to the greater procyclical behavior of margins in concentrated industries. Our constructions of the annual mark-up ratios, for the interval from 1972 through 1986, shows relatively little variation in the price to mark-up ratio in manufacturing durables. By contrast, we observe considerable variation over time in the mark-up ratios in manufacturing nondurables. Among the most variable industries are Food and Kindred Products, Apparel, Printing and Publishing, and Rubber and related Products.

Table 3 **Price over Cost Markup Ratios of Two-Digit SIC Manufacturing Sectors**

SIC Code	Industry Name	1972	1976	1980	1986
	Manufacturing Durables				
32	Stone, Clay and Glass	0.325	0.314	0.301	0.331
33	Primary Metal Products	0.188	0.183	0.179	0.184
34	Fabricated Metal Products	0.252	0.267	0.268	0.257
35	Nonelectrical Machinery	0.285	0.291	0.300	0.285
36	Electrical Machinery	0.285	0.302	0.312	0.322
37	Transportation Equipment	0.208	0.206	0.198	0.220
38	Instruments and Related Products	0.402	0.386	0.384	0.407
39	Miscellaneous Manufacturing	0.291	0.302	0.281	0.320
	Manufacturing Nondurables				
20	Food and Kindred Products	0.197	0.196	0.203	0.271
21	Tobacco Manufactures	0.361	0.390	0.417	0.596
22	Textile Mill Products	0.201	0.194	0.205	0.215
23	Apparel and Other Mill Products	0.224	0.237	0.262	0.276
24	Lumber and Wood Products	0.223	0.232	0.193	0.213
25	Furniture and Fixtures	0.253	0.251	0.268	0.290
26	Paper and Allied Products	0.250	0.259	0.246	0.284
27	Printing and Publishing	0.343	0.349	0.367	0.406
28	Chemicals and Allied Products	0.412	0.371	0.343	0.388
29	Petroleum and Coal Products	0.146	0.130	0.106	0.110
30	Rubber and Plastics Products	0.307	0.290	0.263	0.300
31	Leather and Leather Products	0.228	0.242	0.271	0.247

Recall that equation (7), showing the sensitivity of expected profits to changes in the mean exchange rate, shows that the response of expected profits to exchange rate changes does not depend specifically on the IEE of an industry, but rather on the IEE adjusted for industry mark-ups. Consequently, we use the time series of mark-up ratios to construct the appropriate measures of exposure in testing. An analogous construction, using the formula presented in equations (8), is used for testing the response of investment to changes in the variance of the exchange rate process.

IV: Empirical Implementation and Results

The model of Section II showed that the impact of real exchange rate variability on investment depends on the external exposure of the industry. Using sectoral investment data for the United States manufacturing industries, broken down by 2-digit level to correspond to our exposure indices, we test the following relationship:

$$I_t^i / I_{t-1}^i = \beta_0 + \beta_1 \left(y_{t-1}^i / y_{t-2}^i \right) + \left(\beta_2 + \beta_3 \gamma_t^i \right) e_{t-1} / e_{t-2} + \left(\beta_4 + \beta_5 \gamma_t^i \right) \sigma_{t-1}^e / \sigma_{t-2}^e + \beta_6 r_{t-1} / r_{t-2} + \mu_t^i \quad (11)$$

where I_t^i represents domestic investment in manufacturing sector i (annual time series of investment in new plant and equipment), y_t represents industry sales,[12] e_t is the real exchange rate of the dollar against a trade weighted basket of currencies,[13] σ represents real exchange rate variability, r_t is the United States ten-year Treasury Bill rate.[14] The growth rate of sales in the industry is introduced to control for differences in growth rates across industries.

In equation (11), the effects of exchange rates and of the volatility of exchange rates are permitted to operate in an interacted format. These effects on investment can be independent of the external exposure of the industry (through β_2 and β_4, respectively) or

[12]New Capital Expenditures by Industry. Source: Census of Manufactures, and Annual Survey of Manufactures from the Census Bureau. Disaggregated by broad manufacturing and nonmanufacturing categories. All expenditure figures are reported in constant 1982 dollars. Industry sales data are from the US Department of Commerce.

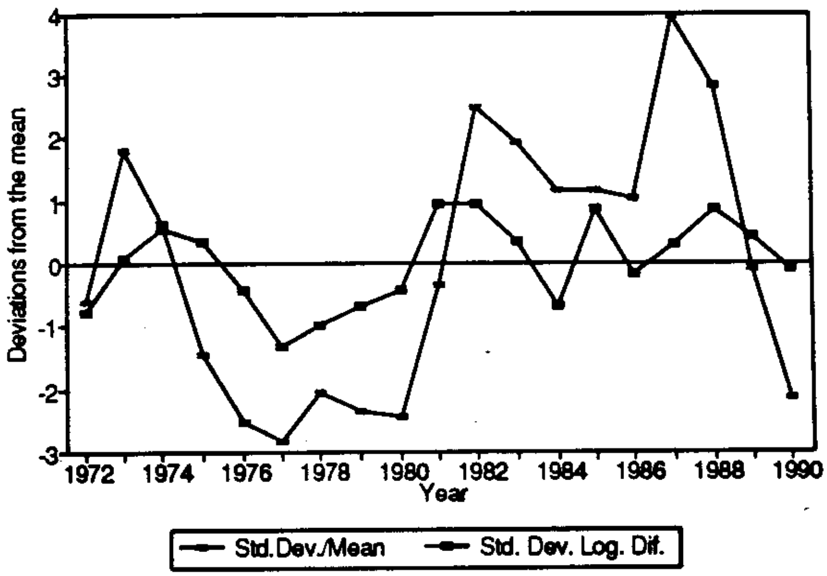
[13]As constructed by the Federal Reserve Bank of Dallas, series RX101. In each period we use the real exchange rate in the fourth quarter of year t. Appreciations (depreciations) are upward (downward) movements of this index. 1985=100. Note that this definition of the exchange rate is the inverse of that defined in Section II.

[14] Source: U.S. Department of Commerce.

influenced by the industry exposure, γ_t^i which alternatively will represent the export share of the industry, the import share of the industry, the IEE[i] of the industry, and, as appropriate, the net exposures constructed using industry markups as in equations (7) and (8) respectively.

Investment decisions are modeled as dependent on current estimates of future exchange-rate variability σ_t. Two estimates of exchange rate volatility are used in our empirical analysis: (i) the ratio of the standard deviation to the mean of the exchange rate index over the previous twelve quarters (EXVOL1); (ii) the standard deviation of the first differences of the logarithm of the exchange rate over the twelve previous quarters (EXVOL2). The latter measure provides the appropriate estimation of σ_t if, as assumed in Section II, the exchange rate follows a lognormal distribution.

Figure 1: Exc. Rate Volatility Estimate
Real U.S. Dollar Index 1972-1990



The correlation coefficients among the two estimates have a mean value of 0.6. Figure 1 presents the volatility series, each graphed in terms of deviations from mean volatility. Two distinct periods for the exchange rate are observed: volatility prior to 1980 was clearly lower than the volatility after 1981. The estimates of volatility also decline after 1987.[15]

Regardless of the choice of volatility measure, a number of econometric issues must be addressed in implementation of equation (11). First, the dependent variable includes real investment of both domestic and foreign origins. An identification problem exists to the extent that contemporaneous investment is correlated with the current exchange rate. We address this problem by proxying the exchange rate with lagged values of the exchange rate.

A second issue is the endogeneity of interest rates. The current interest rate affects the overall manufacturing investment, as well as investment in particular industries, and (through omitted variables bias) may be correlated with the error term u_t^i. We approach this problem by implementing two-stage least squares (2SLS) regressions, using as instruments the other exogenous variables plus the lagged values of the interest rate variable.[16] The testing equation is still of the general form shown in equation (11).We also estimate the system using fixed effects regressions.

<u>RESULTS FROM 2SLS REGRESSIONS:</u> The results from the two-stage regression are presented in Table 4 and Table 5. In Table 4, all industries are pooled together into the same system for inclusion in the 2SLS procedure. In Table 5, the industries included in each of the 2SLS procedures are distinguished according to whether they are durable goods producers, wherein capital investments may be large, or nondurable goods producers. All equations include industry dummies and the standard errors are corrected for heteroskedasticity following White (1980) procedures.

[15]A third measure of volatility, based on predictions by an ARCH(1) model fitted to the quarterly series of the exchange rate, also was considered. This measure had a mean correlation coefficient of 0.42 with the other measures.

[16]The lagged interest rates will be highly correlated with the current interest rate and orthogonal to the error term $u_{i,t}$.

The tables report the results from non-interacted regressions and from regressions in which the effects of exchange rates and exchange rate volatility can depend on one of the following four different measures of the industry's exposure to exchange rates:

(i) EXP_t^i: the export to sales ratio in each industry, χ_t^i. Exchange rate appreciations are expected to reduce industry profitability in relation to export exposure, so that the coefficients β_3 and β_5 are expected to be negative.

(ii) $EFIM_t^i$: the ratio of imported inputs to total inputs in each industry. An appreciation of the domestic currency reduces the cost of production and should be associated with positively signed β_3;

(iii) IEE_t^i: Combined imported input and export dependency using the index of effective exposure constructed for each industry. β_3 is expected to be negative with this index.

(iv) $MKUP_t^i$: The modification of the IEE_t^i to take into account the role of the price over cost markups in the effects of exchange rate movements and exchange rate variability. These measures introduce markup ratios differently for the interacted terms on movements and variability of exchange rates. The exact form of the adjustment corresponds to the derivatives provided in equations (7) and (8). β_3 is also expected to be negative with this index.

In inspecting the tables, first note that investment growth is always positively and significantly correlated with sales growth. The coefficient on the growth rate of sales in an industry is always positive, significant and very close to 1. This result is consistent with the traditional investment literature. In this literature is common to predict a constant ratio of industry sales to industry capital stock, so that both variables should grow at comparable rates.

Table 4

TWO STAGE LEAST SQUARES RESULTS FROM THE POOLED SAMPLE

$$I_t^i / I_{t-1}^i = \beta_0 + \beta_1 \left(y_{t-1}^i / y_{t-2}^i\right) + \left(\beta_2 + \beta_3 \gamma_t^i\right) e_{t-1}/e_{t-2} + \left(\beta_4 + \beta_5 \gamma_t^i\right) \sigma_{t-1}^e / \sigma_{t-2}^e + \beta_6 r_{t-1} / r_{t-2} + \mu_t^i$$

Number of Observations = 280

γ_i	ß1	ß2	ß3	ß4	ß5	ß6	DW
Using EXVOL1							
	.783*	-.780		.122**		-.302	2.07
	.156	.516		.073		.451	
EXP	.837*	-.018	-1.921**	-.013	.458*	.240	2.18
	.134	.304	1.123	.021	.229	.200	
EFIM	.852*	-.544**	1.910*	.089**	-1.120**	.192	2.17
	.134	.283	.945	.051	.617	.257	
IEE	.857*	-.251	-1.957*	.006	.623*	.346	2.14
	.131	.320	.788	.017	.305	.313	
MKUP	.871*	-.167	-1.680**	-.017	.376	.368	2.14
	.131	.328	1.002	.022	.230	.308	
Using EXVOL2							
	.844*	-.380**		.042		.083	2.18
	.132	.202		.265		.302	
EXP	.862*	.233	-1.821**	.006	.401**	.406*	2.13
	.134	.246	1.075	.026	.238	.109	
EFIM	.913*	-.212	1.341**	.061	-.403	.381*	2.12
	.128	.197	.723	.038	.403	.130	
IEE	.879*	-.061	-1.947*	.022	.501*	.472*	2.11
	.128	.196	.643	.023	.225	.148	
MKUP	.883*	-.007	-1.901*	-.008	.408**	.490*	2.11
	.129	.202	.720	.028	.231	.145	

Each equation has been corrected for heteroskedasticity and includes industry dummies.
*** Significant at the 5% level, two-tailed test. ** Significant at the 10% level, two-tailed test.**

The more novel results concern the relationships between exchange rate activity and investment. Exchange rate appreciations are weakly significantly correlated with reduced investment in the pooled sample of United States 2-digit industry when tested without the interacted terms. However, the interacted regression results demonstrate that this effect is far from uniform across industries. As shown in the β_3 column of Table 4, this exchange rate effect on investment increases as the export share of the industry rises, and it declines with the industry's dependence on imported inputs into production.

When the complete sample of industries is divided between durable and nondurable goods manufacturing sectors, we observe a dramatic change in the pattern of significance of exchange rate changes for investment. As shown in the β_3 column of Table 5, exchange rate changes have highly significant effects on investment in durable goods sectors. Regressions which do not adjust for industry exposure significantly underestimate this impact of exchange rates over the estimation period. The direction of these effects on investment in durable goods sectors are fully consistent with the theory provided in Section II. By contrast, exchange rate changes do not have a significant impact on investment in the nondurables sector, regardless of the form of adjustments for import or export exposure.

This interesting distinction between the exchange rate responses of durable and nondurable goods sectors may be related to our earlier observation about the behavior of price-over-cost markups across these two categories of sectors. In nondurables, we observed that industry mark-ups were quite variable, whereas they were relatively stable in durable goods sectors. This could imply that nondurables are able to absorb exchange rate changes in their markups over cost, so that profits are less affected by the exchange rate changes. By contrast, in durables, exchange rate changes pass through into producer profitability and influence their investment decisions in expected directions. Indeed, we also test this assertion and it is confirmed by an examination of the causal relationship between changes in price-over-cost markups and exchange rates. In the nondurables sectors, PCMs fall when the dollar appreciates and rise with an increase in exchange rate volatility. In the durable goods sectors, neither exchange rate levels or volatility significantly influence the PCMs.

Table: 5
TWO STAGE LEAST SQUARES REGRESSION RESULTS
BY INDUSTRY GROUP

$$I_t^i / I_{t-1}^i = \beta_0 + \beta_1 \left(y_{t-1}^i / y_{t-2}^i\right) + \left(\beta_2 + \beta_3 \gamma_t^i\right) e_{t-1} / e_{t-2} + \left(\beta_4 + \beta_5 \gamma_t^i\right) \sigma_{t-1}^e / \sigma_{t-2}^e + \beta_6 r_{t-1} / r_{t-2} + \mu_t^i$$

γ_i	β_1	β_2	β_3	β_4	β_5	β_6	DW
EXVOL1	NONDURABLES, N = 168						
EXP	.845*	-.144	-1.947	-.056	1.448**	.113	1.96
	.151	.355	1.872	.039	.755	.239	
EFIM	.799*	-.414	1.621	.091	-1.240	.112	2.01
	.147	.356	1.141	.057	.816	.308	
IEE	.824*	-.322	-1.583	.025	1.108*	.123	1.96
	.138	.365	.973	.022	.548	.338	
MKUP	.861*	-.318	-.818	-.048	1.253**	.103	1.97
	.142	.371	1.149	.038	.760	.337	
EXVOL1	DURABLES, N = 112						
EXP	.867*	.429	-3.096*	-.003	.221	.528	2.45
	.260	.573	1.459	.042	.299	.349	
EFIM	.972*	-1.029	4.210*	.126	-1.675	.511	2.39
	.295	.660	1.918	.188	1.865	.546	
IEE	.956*	.163	-3.540*	-.020	-.034	1.146	2.31
	.279	.721	1.492	.029	.596	.780	
MKUP	.956*	.299	-4.050*	-.026	.105	1.114	2.32
	.269	.705	1.952	.046	.347	.694	
EXVOL2	NONDURABLES, N = 168						
EXP	.868*	.031	-.730	.002	.610	.273*	1.97
	.151	.327	2.520	.037	.672	.123	
EFIM	.854*	-.121	1.219**	.075**	-.703**	.279**	1.96
	.142	.244	.725	.040	.362	.161	
IEE	.855*	-.038	-1.211	.037	.608**	.304**	1.95
	.140	.248	.787	.030	.004	.161	
MKUP	.872*	-.043	-.946	-.006	.743	.300**	1.95
	.142	.248	.888	.035	.530	.155	
EXVOL2	DURABLES, N = 112						
EXP	.875*	.644	-3.031*	.012	.146	.662*	2.39
	.258	.410	1.265	.055	.330	.181	
EFIM	1.032*	-.722**	3.330**	.112	-1.016	.582*	2.37
	.257	.388	1.868	.104	1.076	.217	
IEE	.951*	-.102	-3.273*	-.022	.271	.885*	2.41
	.252	.293	1.075	.042	.355	.278	
MKUP	.954*	.067	-3.540*	-.036	.184	.909*	2.40
	.254	.059	1.156	.059	.344	.269	

Each equation has been corrected for heteroskedasticity and includes industry dummies.
* Significant at the 5 % level, 2-tailed test. ** Significant at the 10 % level, 2-tailed test.

The results in tables 4 and 5 imply an important time pattern of the effects of changes in exchange rates and the behavior of industry investment. The results for the aggregate sample seem to suggest very small quantitative impact of exchange rate changes on investment: on average a 10% appreciation of the exchange rate caused only about a .5% decline in the level of investment.[17] But these pooled sample results are misleading for two reasons: (1) the effects of exchange rates have changed sharply over time in relation to the evolving external exposure of industries, and (2) durable and nondurable goods sectors have been affected very differently.

As we saw in the previous section, the average net exposure of manufacturing industries to exchange rate has evolved from being primarily export exposed to import exposed towards the end of the sample. This change in net exposure over time implies that appreciations of the exchange rate during the 1970s until 1983 implied decreases in investment, while in the remaining years of the 1980s exchange rate appreciations implied higher industry investment.[18] As shown in Figure 2, in the seventies a 10% appreciation of the exchange rate caused on average a .5% decrease in investment while by 1986 the same change in the exchange rate would result in a .12% increase in investment.

Since there is a dramatic difference between the effects of exchange rates on nondurable and durable industries, the complete pooling results also do not provide an accurate description of the response of investment. In durable goods sectors, in the 1970s a 10% appreciation resulted on average in a decrease in investment in the neighborhood of 1.1%, while by 1986 this same appreciation would have lead to an increase in investment of 0.64%. For nondurable industries the effects of exchange rates are not statistically significant. Even so, the predicted effect of a 10 percentage appreciation would be a

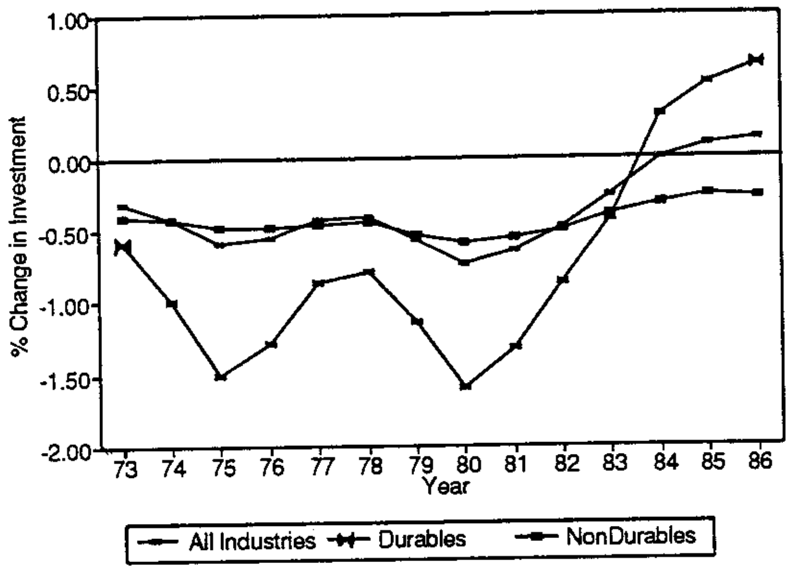
---

[17]The quantitative results reported here and below were computed according to the parameters from the regression equations using the MKUP series and the EXVOL2 measure of volatility.

[18]Alternatively, depreciations of the exchange rate during the 1970s (and until approximately 1983) implied increases in investment while in the last years of the sample exchange rate depreciations implied lower industry investment.

contraction of investment by a relative steady 0.4% percentage change over both the 1970s and the 1980s.

Figure 2
Effects of a 10% Dollar Appreciation



The effects of exchange rate variability on investment are captured by the β_4 and β_5 coefficients in Tables 4 and 5. The pooled sample results show that exchange rate variability had a very small quantitative effect on investment, with the sign of this effect negative in most periods. The larger negative effects are in durable goods sectors, wherein a 10 percent increase in volatility lead to a .3 percent decline in investment, but these effects are not statistically significant. The sign patterns on the interacted terms for exposure are consistent with the theoretical arguments provided in Section II, but the results are only weakly significant. These results are consistent with those theories based on firms behaving in a risk averse manner or with production irreversibilities, and contradict those arguments from the production flexibility literature wherein uncertainty leads to higher expected industry profits and therefore higher investment.

RESULTS FROM FIXED EFFECT REGRESSIONS: We also consider the effects of exchange rate levels and volatility on investment under the assumption that the interest rate affects overall investment in any given period, but may not effect the share of aggregate investment that is allocated to any individual industry i, shI_t^i. This implicitly assumes that firms in different industries react in the same manner and magnitude to changes in the interest rate. To the extent that this assumption holds, the relative investment allocated to any industry will be independent of that period's interest rate. Moreover, the common effects of exchange rate levels and volatility also will be eliminated, leaving only the interacted components of these variables. Based on these observation we estimate the following fixed effects equation

$$shI_t^i / shI_{t-1}^i = \beta_0 + \beta_1\left(y_{t-1}^i / y_{t-2}^i\right) + \beta_2\gamma_t^i \, e_{t-1}/e_{t-2} + \beta_3\gamma_t^i\sigma_{t-1}^e / \sigma_{t-2}^e + \mu_t^i \qquad (12)$$

The results from this model still show that those sectors with relatively high sales growth also significantly expand their share of aggregate investment. This result is consistent with our previous findings and intuitively plausible.

However, the fixed effects model performs poorly when applied to the exchange rate issue. Across the range of specifications, exchange rate levels generally do not enter significantly into these share equations and variability is correlated significantly with increased investment shares only when the IEE measure is used. Given the overall poor performance of the fixed effects model, we conclude that the assumptions on which this regression specification are based do not adequately suit the investment data, and we do not report the results.

SECTION V: CONCLUSIONS

Most U.S. manufacturing industries have considerably increased their external exposure over time, and on average have evolved from being net exporters in the 1970s to net importers in the 1980s. This increase in exposure has worked through increased reliance on imported inputs rather than through reductions in export shares. These patterns in imported input and export exposure are important for the transmission of exchange rate effects into sectoral investment behavior. Without making appropriate adjustments, we have shown that regression analysis may both fail to capture and understate the importance of exchange rates for real economic activity.

The change in net exposure over time implies that appreciations of the exchange rate during the 1970s and until approximately 1983 implied decreases in investment while in the last years of the sample exchange rate appreciations implied higher industry investment. In the 1970s a 10% appreciation of the exchange rate caused on average a .5% decrease in investment, while by 1986 the same change in the exchange rate would result in a .7% increase in investment.

We also found striking differences between the effects of exchange rates on nondurable and durable industries. In nondurable sectors, in the 1970s a 10% appreciation resulted on average in a decrease in investment in the neighborhood of 1.2%, while by 1986 this same appreciation would have lead to an increase in investment of 0.7%. For nondurable industries the effects of exchange rates are not statistically significant. Even so, the predicted effect of a 10 percentage appreciation would be a contraction of investment by a relative steady 0.4% percentage change over both the 1970s and the 1980s.

We also have found that exchange rate variability has weakly significant effects on real domestic investment activity. The significance of the effect may be missed by regressions that impose parameter stability. Exchange rate variability is associated with reduced investment in United States industry, in particular in durable goods sectors. This result lends support to arguments about volatility influencing investment through risk aversion of producer/investors, rather than via production flexibility motives. Regardless, the impact of exchange rate volatility on domestic investment is not quantitatively large.

The research results provided in this paper open further questions for exploration and also provides cause for reexamination of other previously examined issues. We have shown that -- in addition to the export and imported input exposures-- the price-over-cost markup ratios and industry competitive structures are important for our understanding of the real effects of exchange rates. These channels warrant further analysis, perhaps using the lessons from the recent literature on exchange rate pass through and market structure to further explore the real implications of exchange rate movements. Another channel for further study is the importance of domestic versus foreign competition in an industry and the potential for strategic investments in response to exchange rate patterns.

We have emphasized throughout this paper that one must adjust for both export shares and imported inputs into production in order to properly assess the real implications of exchange rate movements and volatility. While we have made this argument in the context of investment activity, it is equally relevant for studies of the export and trade volume effects of exchange rates. The existing literature on this topic often is criticized for inconclusive results, since the empirical findings are sensitive to the country choice and time frames selected for empirical estimation. Our results suggest that those studies may be misspecified and may benefit from a reexamination using the methodology applied in this paper.

REFERENCES

Abel, A. (1983) "Optimal Investment Under Uncertainty," *American Economic Review* vol. 73 no.1 pp.228-33.

Aizenman, J. (1992) "Exchange Rate Flexibility, Volatility and Patterns of Domestic and Foreign Direct Investment," forthcoming *IMF Staff Papers*.

Baldwin, R. and P. Krugman (1989), "Persistent Trade Effects of Large Exchange Rate Shocks", *The Quarterly Journal of Economics* vol.CIV, no. 4 (November) pp.635-654.

Bell, G. and J. Campa, (1991), "Irreversible Investments and Uncertainty: A Study of the Chemical Processing Industry," Stern School of Business, working paper IB-91-5.

Caballero, R. (1991) "On the Sign of the Investment-Uncertainty Relationship," *American Economic Review* vol.81 no.1 (March) pp.279-288.

De Meza, D. and F. van der Ploeg (1987), "Production Flexibility as a Motive for Multinationality," *Journal of Industrial Economics* vol.35 no.3 (March) pp.343-351.

Dixit, A., (1989) "Entry and Exit of Firms under Uncertainty", *Journal of Political Economy* vol.97, no.3 pp.620-638.

Domowitz, I., Hubbard, G. and B. Petersen (1986), "Business Cycles and the Relationship between Concentration and Price-Cost Margins," *Rand Journal of Economics* vol. 17, no.1 (Spring) pp.1-17.

Froot, K., and J. Stein (1991), "Exchange Rates and Foreign Direct Investment: An Imperfect Capital Markets Approach", *Quarterly Journal of Economics* (November) pp.1191-1217.

Goldberg, L. (1991), "Exchange Rates and Investment in United States Industry", manuscript, New York University. [Revised NBER working paper #3249].

Goldberg, L. (1990), "Measuring External Openness: The Index of Effective Exposure" C.V. Starr Center working paper 90-19 (May).

Goldberg, L. and C. Kolstad (1993) "Foreign Direct Investment, Exchange Rate Variability, and Demand Uncertainty" manuscript (April).

Hall, R. (1988), "The Relation between Price and Marginal Cost in United States Industry," *Journal of Political Economy*, vol.96 no.5 pp.921-947.

Hartman, R. (1972), "The Effects of Price and Cost Uncertainty on Investment," *Journal of Economic Theory* (October) vol.5 pp.258-266.

Jorion, P. (1990), "The Exchange Rate Exposure of U.S. Multinationals," *Journal of Business* vol.63, no.3, pp.331-345.

Klein, M. (1990), "Sectoral Effects of Exchange Rate Volatility on United States Exports," *Journal of International Money and Finance*, vol. 9 pp.299-308.

Lipsey, R.E., (1988) "Changing Patterns of International Investment in and by the United States", in Martin Feldstein *The United States in the World Economy*, Chicago and London, University of Chicago Press pp.475-545.

Luehrman, T. (1991), "Exchange Rate Changes and the Distribution of Industry Value," *Journal of International Business Studies*, vol.22 no.4, pp.619-650.

Pindyck, R. (1988), "Irreversible Investment, Capacity Choice, and the Value of the Firm," *American Economic Review* (December) vol.78 pp.969-985.

Ungern-Sternberg, T. and Weizacker, C.C. (1990), "Strategic Foreign Exchange Management," *Journal of Industrial Economics*, vol.xxxvII no.4 (June) pp.381-395.

White, H. (1980), "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity," *Econometrica* vol.48 pp.817-38.

Wolak, F. and C. Kolstad (1991), "A Model of Homogeneous Input Demand Under Price Uncertainty," *American Economic Review* vol.81 no.3 (June) pp.514-538.

APPENDIX 1

The log-normal density function is given by

$$f\left(x|\bar{x},\sigma_x^2\right)=\frac{1}{(2\pi)^{1/2}\sigma_x}\exp\left[-\frac{1}{2}\left(\frac{\log x-\bar{x}}{\sigma_x}\right)^2\right]\text{ for }0<x<\infty;=0\text{ for }x\leq 0.$$

Using equations (3) and (5), under lognormally distributed exchange rates expected profits are computed to be:

$$E(\pi^i)=p_i(q_i)q_i+\exp\left(\mu+\frac{1}{2}\sigma^2\right)p_i^*(q_i^*)q_i^*-\exp\left(\alpha_i\mu+\frac{1}{2}\alpha_i^2\sigma^2\right)\cdot w^{1-\alpha_i}w^{*\alpha_i}(q_i+q_i^*)$$

and $\dfrac{\partial E(\pi^i)}{\partial\mu}\Big/TR_i=\chi_i-\varphi_i\alpha_i$

where

$$\chi_i=\frac{P_i^*(q_i^*)\cdot q_i^*\exp\left(\mu+\frac{1}{2}\sigma^2\right)}{P_i(q_i)\cdot q_i+P_i^*(q_i^*)\cdot q_i^*\exp\left(\mu+\frac{1}{2}\sigma^2\right)}\quad\text{and}\quad\varphi_i=\frac{w^{*\alpha_i}w^{1-\alpha_i}(q_i+q_i^*)\exp\left(\alpha_i\mu+\frac{1}{2}\sigma^2\alpha_i^2\right)}{P_i(q_i)\cdot q_i+P_i^*(q_i^*)\cdot q_i^*\exp\left(\mu+\frac{1}{2}\sigma^2\right)}$$

As noted in the text, one also can model the investment equation as a function of the expected variability of profits in addition to just modelling investment as dependent on the expected level of profits. In this case, one would rewrite equation (1) as

$$I^i=\phi\left(E\left(\pi^i(e,p_i,w,w^*)\right),vol\left(\pi^i(e,p_i,w,w^*)\right),r\right)$$

The sign of ϕ_2 is unresolved theoretically and remains an empirical question. Given this investment specification, in order to complete our description of the relationship between exchange rate processes and firm level investment decisions, we need to compute the variability of the profits of the firm:

$$Var(\pi^i)=\sigma^2\left(p_i^*(q_i^*)q^*\right)^2+Var(e^{\alpha_i})\cdot\left(w^{1-\alpha_i}w^{*\alpha_i}(q_i+q_i^*)\right)^2$$
$$-2\left(p_i^*(q_i^*)q_i^*\right)\cdot\left(w^{1-\alpha_i}w^{*\alpha_i}(q_i+q_i^*)\right)Cov(e^{\alpha_i},e)$$

Under lognormally distributed exchange rates, the derived response of profit variability to alterations in the mean and variance of exchange rates, normalized by squared total industry revenues, are highly nonlinear expressions.

$$\frac{\partial Var(\pi^i)}{\partial \mu}\Big/ TR_i^2 = 2\left[\chi_i^2\left(\exp(\sigma^2)-1\right)+\alpha_i\varphi_i^2\left(\exp(\alpha_i^2\sigma^2)-1\right)-\chi_i(1+\alpha_i)\left(\exp(\alpha_i\sigma^2)-1\right)\right]$$

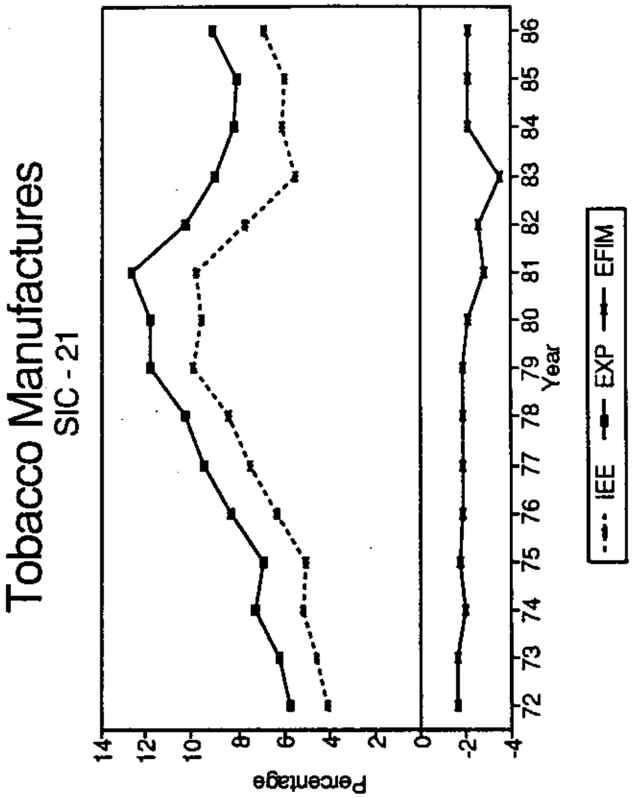
$$\frac{\partial Var(\pi^i)}{\partial \sigma^2}\Big/ TR_i^2 = \chi_i^2\left(2\exp(\sigma^2)-1\right)+\varphi_i^2\left(2\alpha_i^2\exp(\alpha_i^2\sigma^2)-1\right)-2\chi_i\varphi_i\left[\frac{1}{2}(1+\alpha_i)^2\exp(\alpha_i\sigma^2)-1\right]$$

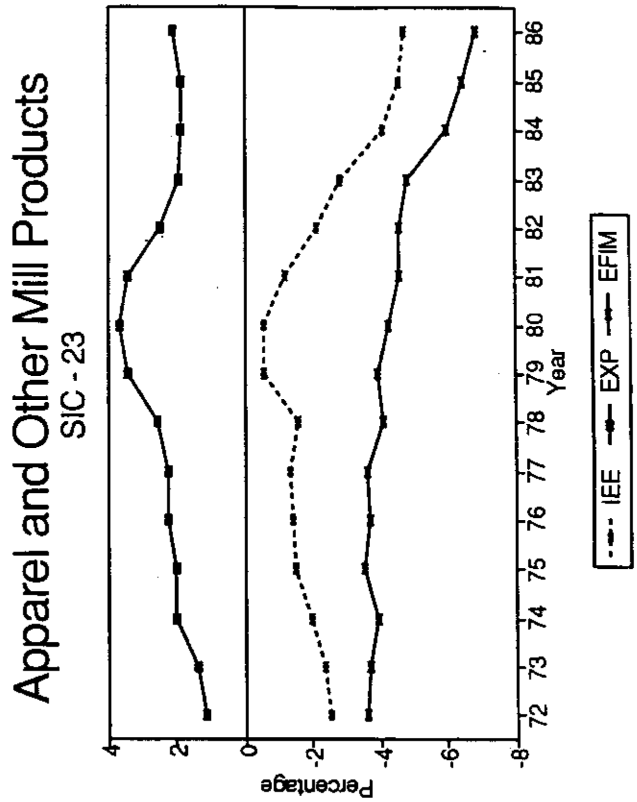
Under complete monopoly, the variance of profits is increasing in both μ and σ^2. In this case, however, profitability is not effected by changes on the cost side of the equation. More general results, and those relevant to all of the industries that we are studying, require numerical computation of these derivatives. Since these derivatives are not particularly intuitive and are highly model specific, in our empirical analysis we have restricted our attention to the effects of the mean and variance of the exchange rate process on expected industry profits.

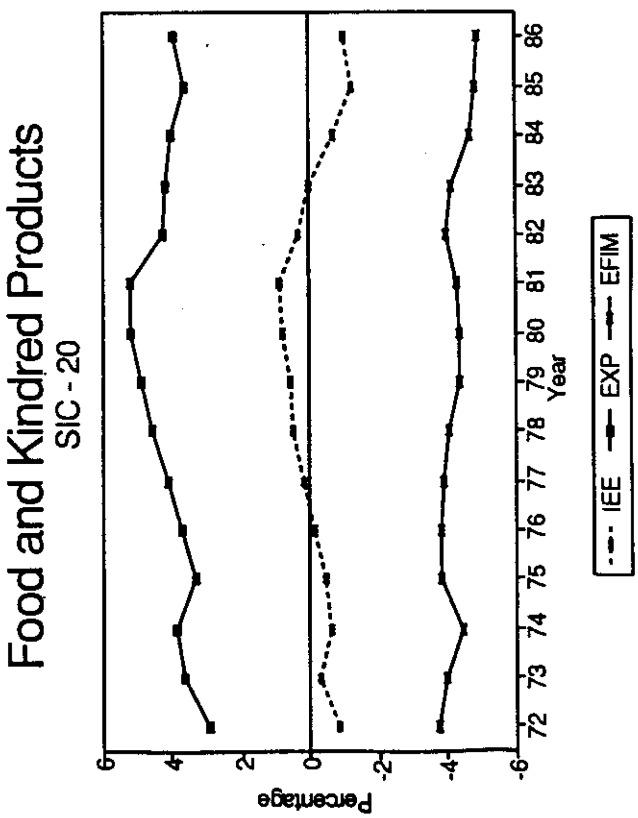
APPENDIX 2

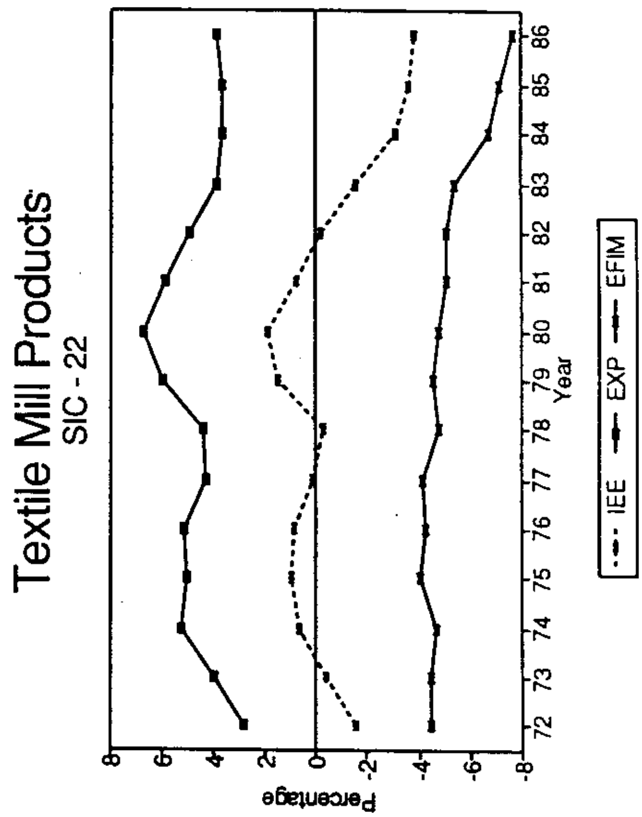
EXPORT (EXP), IMPORTED INPUT (EFIM) AND NEX EXPOSURE (IEE) INDEX OF U.S. TWO-DIGIT MANUFACTURING SECTORS

Manufacturing Nondurables

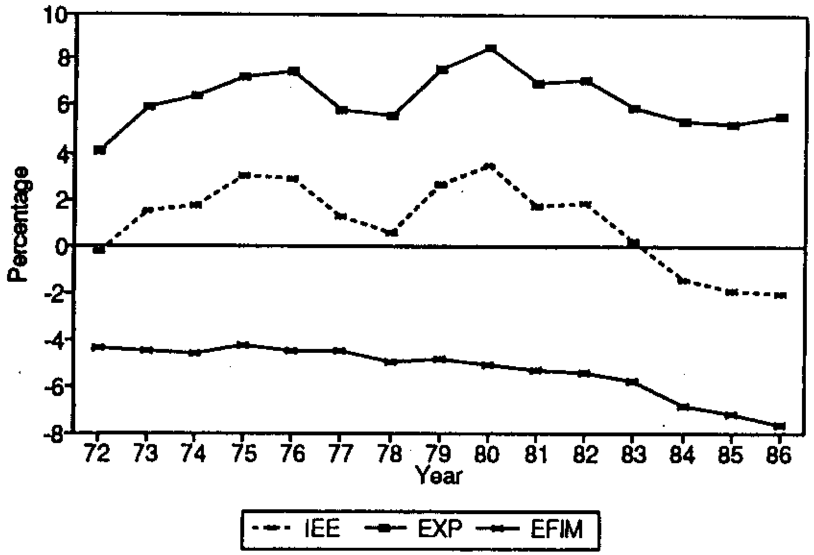




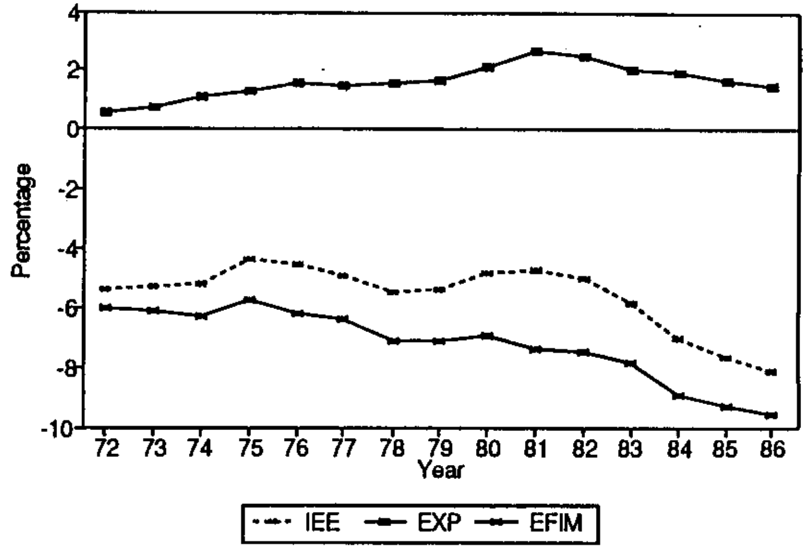




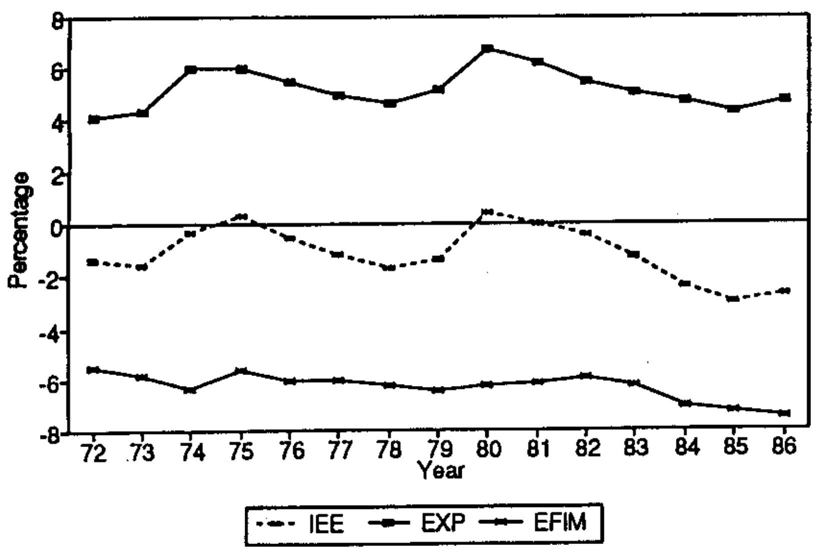
Lumber and Wood Products
SIC - 24



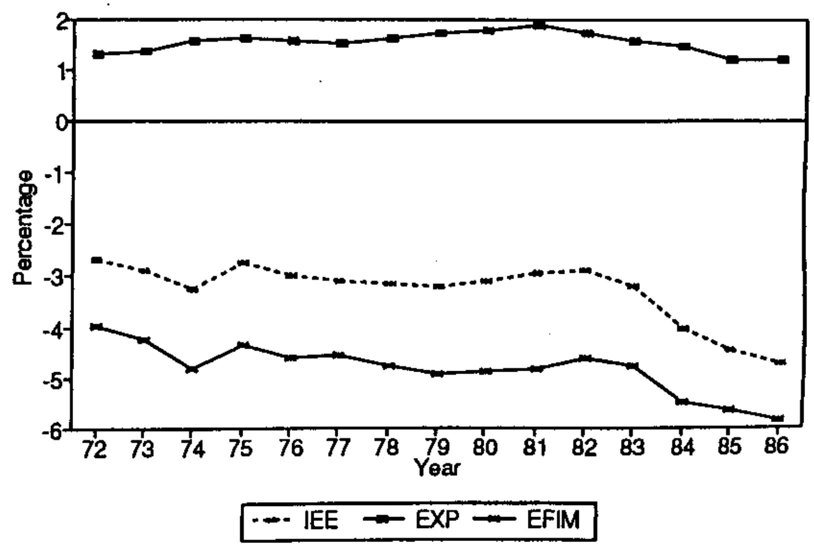
Furniture and Fixtures
SIC - 25



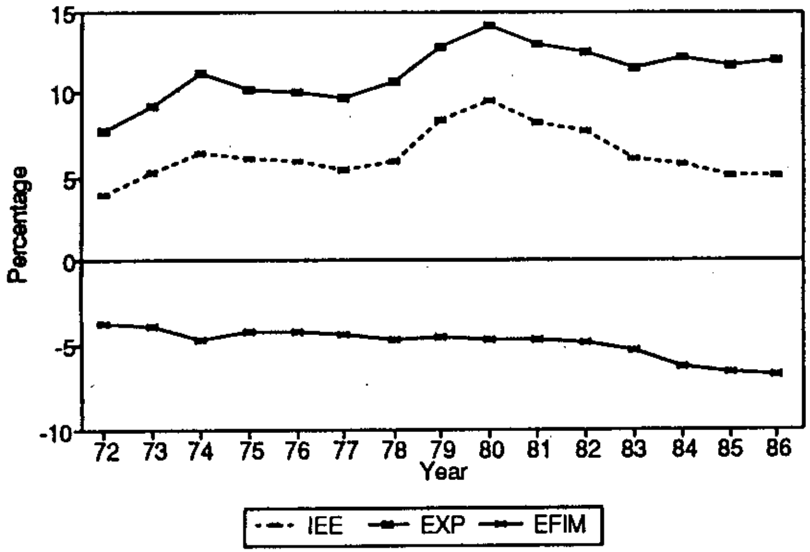
Paper and Allied Products
SIC - 26



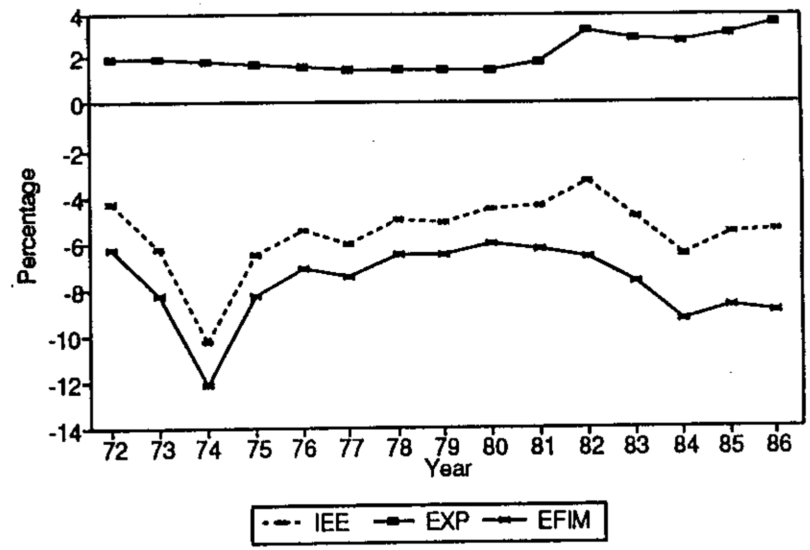
Printing and Publishing
SIC - 27



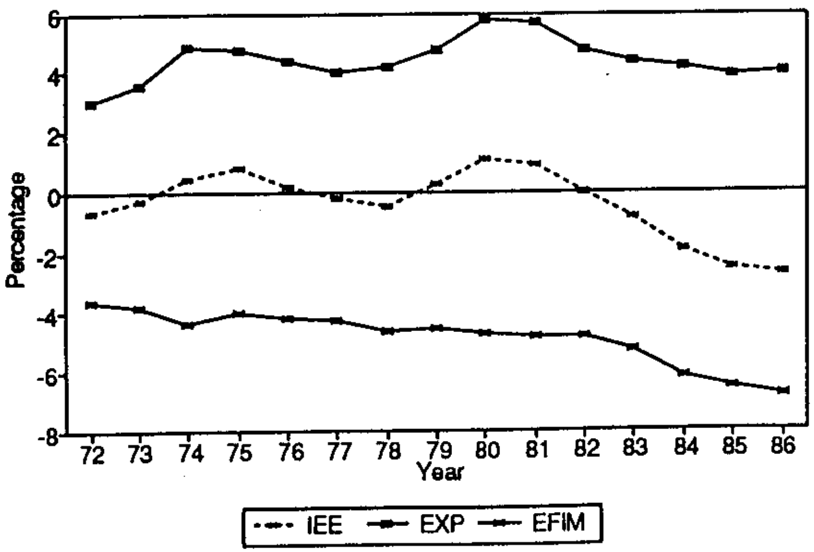
Chemical and Allied Products
SIC - 28



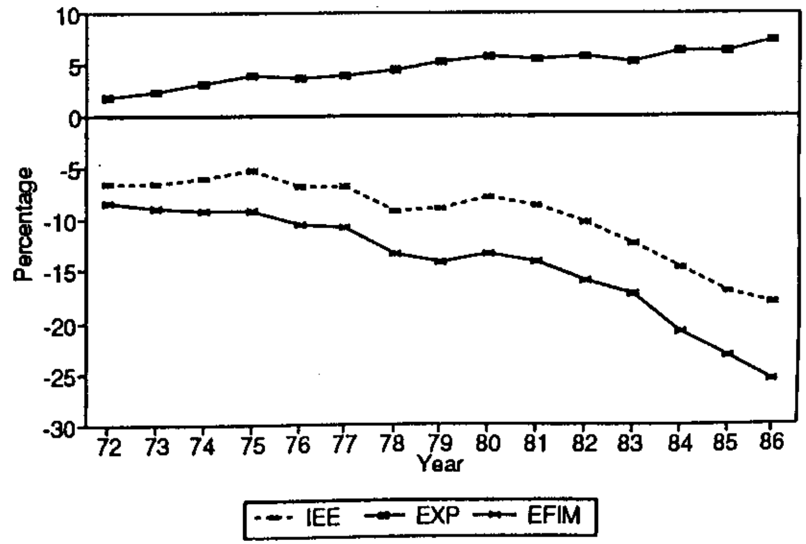
Petroleum and Coal Products
SIC - 29

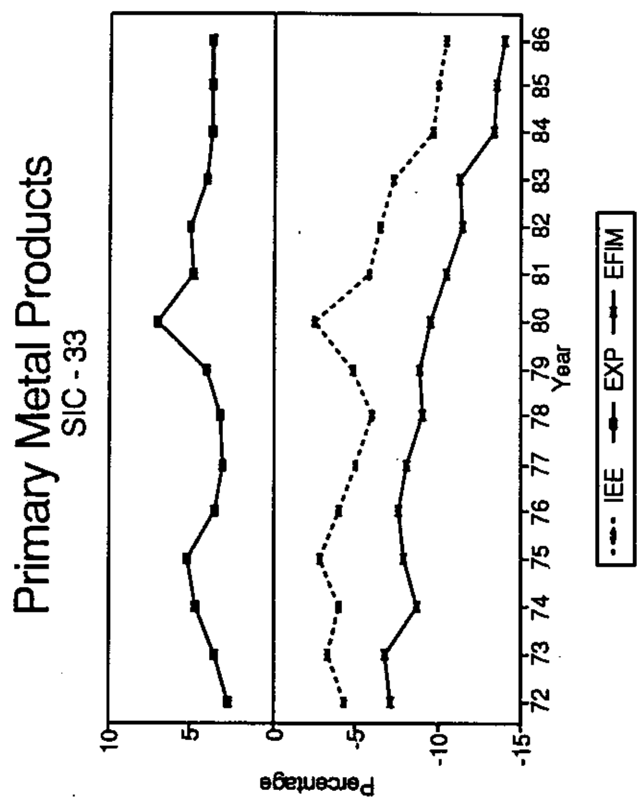


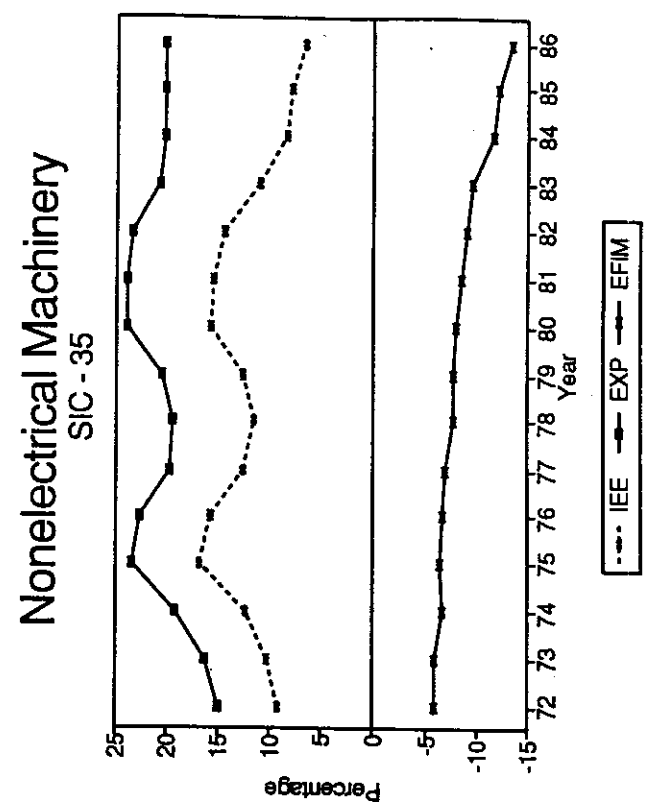
Rubber and Plastics Products
SIC - 30

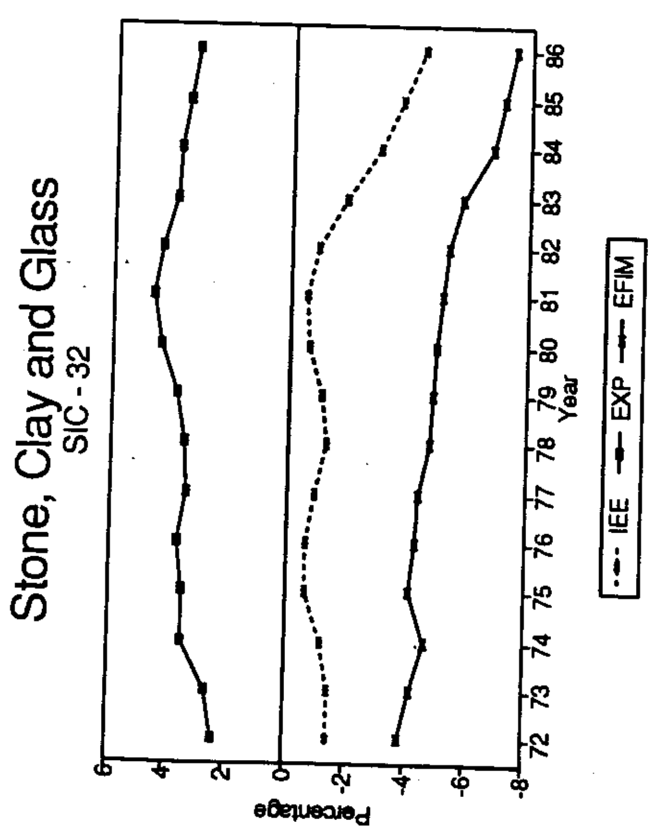


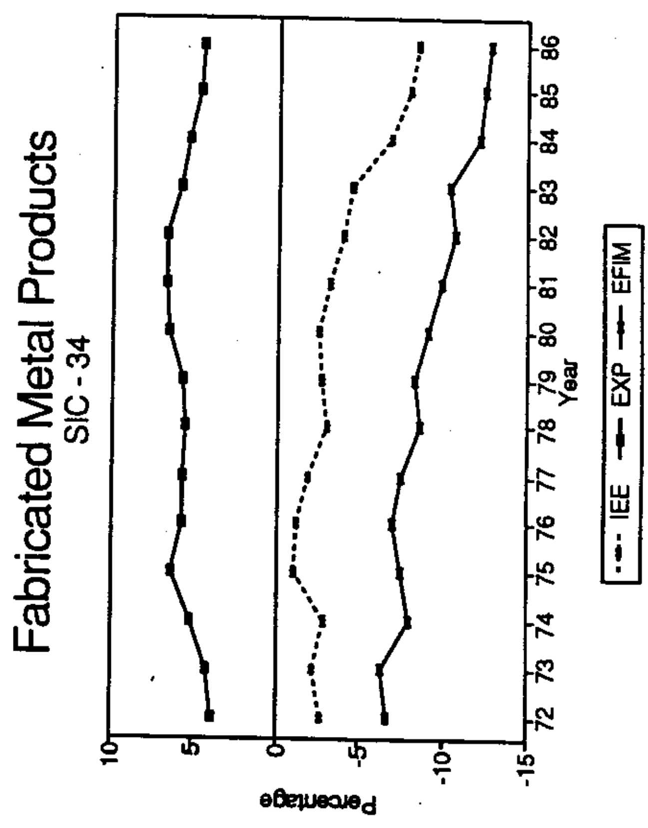
Leather and Leather Products
SIC - 31



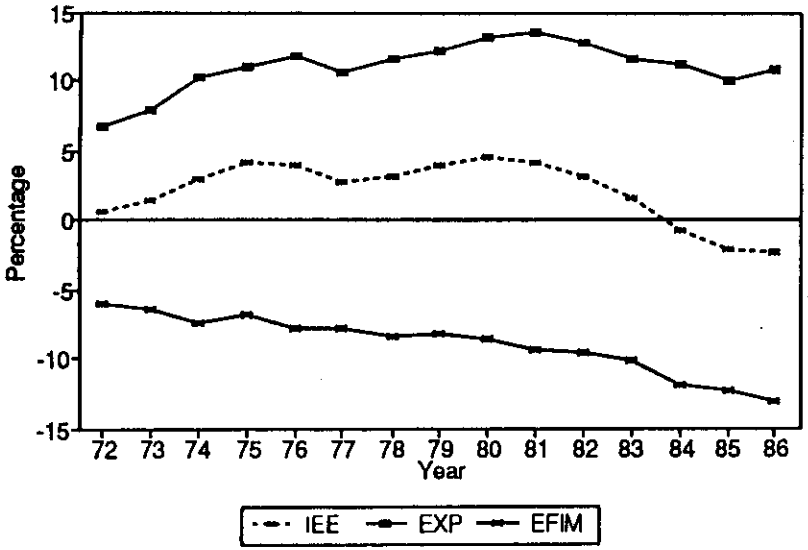

Primary Metal Products
SIC - 33
Percentage
Year
IEE
EXP
EFIM


Nonelectrical Machinery
SIC - 35
Percentage
Year
IEE
EXP
EFIM

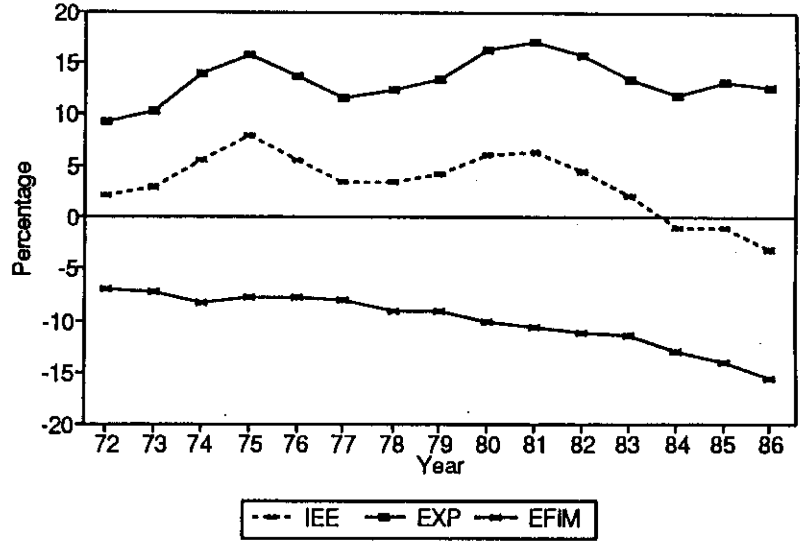

Stone, Clay and Glass
SIC - 32
Percentage
Year
IEE
EXP
EFIM


Fabricated Metal Products
SIC - 34
Percentage
Year
IEE
EXP
EFIM

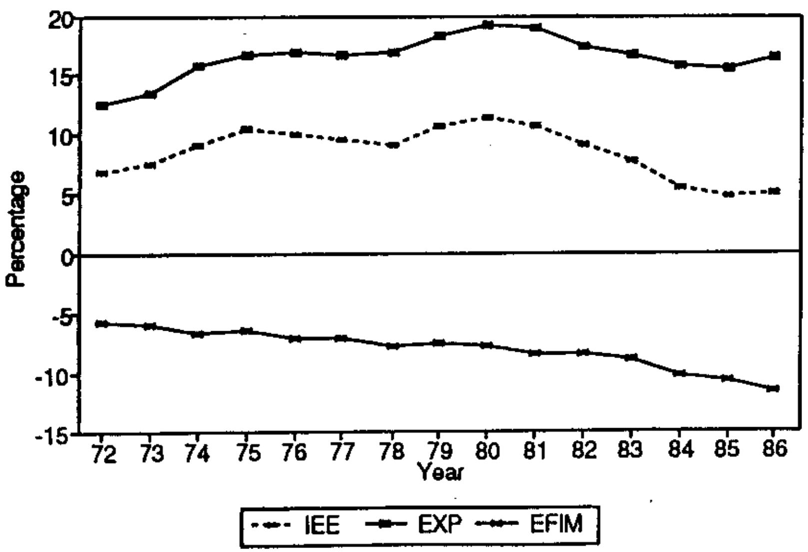
Electrical Machinery
SIC - 36



Transportation Equipment
SIC - 37



Instruments and Related Products
SIC - 38



Miscellaneous Manufacturing
SIC - 39