Investment, GNP, and real exchange rates

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The value of the U.S. dollar varied widely over the 1963-1986 time period. Those same years witnessed several cyclical expansions and contractions and even wider swings in aggregate fixed investment rates. One explanation for some of the investment rate swings is the dramatic movements in exchange rates over this period. In this article, I use newly constructed capital stock and investment series for 270 U.S. manufacturing industries to examine investment responsiveness to changes in real exchange rates for 1963-1986. My research shows that investment rates are sensitive to real exchange rate movements and that appreciation of the U.S. dollar is associated with a decrease in industry investment rates—particularly in durable goods industries. Analysis of industries for which imports-sales data are available further suggests that investment is more responsive in industries with greater exposure to foreign competition. Finally, I document the existence of substantial interindustry variation in the influence of real exchange rates on investment. My results are broadly consistent with international trade models in which changes in real exchange rates drive changes in the relative competitiveness of domestic and foreign industries.

Changes in real exchange rates are often thought to reflect changes in the international competitiveness of domestic and foreign industries. For example, the depreciation of the dollar is said to be correlated with improved competitiveness of U.S. firms, because U.S. and foreign consumers find it relatively cheap to buy U.S. goods. In the long run, being competitive in international markets requires investing in capital equipment that will be used to satisfy current and future market demand. This suggests that real exchange rate movements are correlated with changes in international competitiveness now and will continue to be in the future. By analyzing the extent to which investment spending of U.S. manufacturing industries has historically varied with changes in the value of the dollar, I indirectly examine how internationally competitive the U.S. manufacturing sector will be in the future.

The article is organized as follows. The next section outlines the expected effects of changes in the value of the dollar on output and input demands of U.S. manufacturing industries. The third section describes the data used in the article, and the fourth reports the results. Conclusions are in the final section.

Why should real exchange rates matter?

Movements in the value of the dollar will affect the input and output choices of U.S. manufacturing firms as long as the goods produced are tradeable, that is, as long as output demand is sensitive to the relative price of domestic and foreign goods. Simply put, an

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appreciation of the dollar lowers the relative price of foreign goods to U.S. goods. This causes demand for domestically produced goods to fall and, as a consequence, reduces input demands in the affected sectors.

The appropriate measure of the relative price of home and foreign goods is the real exchange rate, which depends on the nominal exchange rate and home and foreign prices. To illustrate this relationship, consider Equation (1), where E is the nominal exchange rate, expressed in terms of units of foreign currency per U.S. dollar, and P_{US} (P_F) is the price level of the United States (foreign country). Equation (1) shows that the real exchange rate, e, is defined as

$$(1) \quad e = E^* \frac{P_{US}}{P_F}.$$

The idea behind many theories of international trade is that increases in e (appreciation of the dollar) cause decreases in domestic output and derived input demands. According to this view, the size of the output response in any given sector or industry will depend on the relevant demand elasticities and the expected persistence of the exchange rate shock. In turn, technologically determined elasticities of substitution and adjustment costs will determine the size of the input demand response.[1] Shocks that are expected to be permanent may be met with changes in inputs that are relatively costly to adjust, such as capital, while more transitory shocks may be met with change in more easily altered inputs, such as labor. Furthermore, firms may alter prices instead of outputs and inputs, so that price-cost margins may also be affected when real exchange rates change.

In this article, I do not seek to directly develop and test a model of real effects of exchange rate movements. Instead, I focus on the correlation between changes in the demand for one particular input, capital, and changes in an index of the real value of the dollar.[2] Changes in the demand for capital, as measured by investment spending, are of interest because of the strong empirical evidence that investment spending is a large and cyclically sensitive component of U.S. total aggregate spending. Because industries differ widely with respect to their output and input demand elasticities as well as in their exposure to international markets, I expect to observe substantial cross-sectional variation in the relationship between exchange rates and investment rates. My analysis relies on the assumption that changes in e are exogenous at the individual industry level, that is, that the exchange rate is not affected by the actions of individual industries. This exogeneity assumption has been exploited by other researchers interested in measuring the impact of exchange rate movements on industry outputs and inputs.[3]

The present analysis is only a first step towards understanding the relationship among investment spending, exchange rate movements, and international competitiveness. The evidence for the patterns documented here is suggestive, not conclusive, about the nature of this relationship, and this article lays the groundwork for future analysis.

A review of the data

The industry data used in this article are annual figures for a subset of U.S. four-digit Standard Industrial Classification (SIC) manufacturing industries during the years 1963-1986.[4] After elimination of industries with missing data, 270 industries remain in the data set. The data are derived from the *Census of Manufactures* and the *Annual Survey of Manufactures* and were originally assembled by Domowitz, Hubbard, and Petersen (DHP) (1987). Data on capital stocks and investment, as well as other variables, are included in the data base, and the original data were used to construct several series used in this article. Capital stock series were computed by applying standard recursion formulas to benchmark stocks. See the Box for details.

Table 1 gives the reader some background information on the industries studied here. The Table reports the full sample means and standard deviations for the gross investment rate, the sales to capital ratio, and the price-cost margin, and it also presents the same statistics for durable goods and nondurable goods industries separately.[5] The mean gross investment rate in the sample was .132, and the average sales to capital ratio was 5.11, implying a .20 capital-sales ratio. Durable goods industries are characterized by higher levels of capital intensity, higher investment rates, and higher price-cost margins than nondurable goods industries.[6]

Because investment spending is highly procyclical, I need to control for the level of macroeconomic activity in the analysis below. I use the ratio of actual to potential gross national product (GNP) for each year in the sample as my

Data sources and construction

Data for the four-digit SIC industries are obtained from the data of Domowitz, Hubbard, and Petersen (DHP) (1987), who assembled the set from various years of the *Census of Manufactures* and *Annual Survey of Manufactures*. DHP's original data set was updated and expanded at the Federal Reserve Bank of Chicago. Macroeconomic data are obtained from the National Income and Product Accounts (NIPA). Specifically, the following definitions and procedures were used in constructing the data set used in this article. Unless otherwise noted, the annual data cover the 1963-1986 time period.

Investment

The Census reports total gross investment (dollars spent on new capital goods) in current (nominal) dollars.

Capital stock

The Census contains gross stock figures, but these data are not good measures of capital for at least two reasons. First, the data embody an assumption of "one-horse-shay" depreciation.* Second, because stocks purchased at different times are added together, it is difficult to correct for changes in the price of capital goods. Consequently, I construct a current (nominal) dollar capital stock series for each industry by applying a standard capital accumulation relationship to a benchmark capital stock. I use an annual geometric depreciation rate (δ) for the total capital stock of .0926, computed by the Bureau of Economic Analysis (BEA) and cited in Shapiro (1986). The capital accumulation equation embodies the "time-to-build" assumption and applies depreciation only to the current stock, not to the current year's investment:

$$(1)\quad K_{it} = I_{it-1} + \left\{\frac{p^k_t}{p^k_{t-1}}\right\} K_{it-1}(1-\delta),$$

where K_{it} is the capital stock and p^k_t is the implicit price deflator for capital goods, taken from NIPA. I use the 1958 gross stocks as benchmarks.

Gross investment rate

The gross investment rate is defined as the ratio of gross investment expenditures to the previous year's capital stock: I_{it}/K_{it-1}, where both I_{it} and K_{it-1} are measured in current dollars.

Nominal sales

Nominal sales is defined as output minus the value of final goods inventory changes. Specifically, $S_{it} = VAD_{it} + CM_{it} - TINTY_{it} + TINTY_{it-1}$, where *VAD* is value added, *CM* is cost of materials, and *TINTY* is final goods inventories, all taken directly from the Census. The sales-capital ratio, S_K_{it}, is defined as $S\_K_{it} = S_{it}/K_{it-1}$.

Price-cost margin

The price-cost margin (PCM_{it}) is defined as $(VAD_{it} - PAY_{it})/(VAD_{it} + CM_{it})$, where *PAY* is total payroll, which is reported directly by the Census.

Macroeconomic measures

I used the actual and potential gross national product (GNP) figures reported in NIPA, and I defined A_PGNP_t as the ratio of actual to potential GNP in year *t*. This measure is identical to the one used by Petersen and Strauss (1989, 1991).

*See Hulten and Wykoff (1981) for evidence that depreciation patterns tend to be geometric.

measure of aggregate economic activity. The mean of this ratio over the 1963-1986 time period is 1.00. The real exchange rate measure used in this article is the real, trade-weighted index of the U.S. dollar developed at the Federal Reserve Bank of Chicago. This index, which is described in detail by Hervey and Strauss (1987a, 1987b, 1987c), was originally developed to measure exchange rate movements over the 1971-1986 time period and has recently been extended as far back as 1960. The index includes 16 countries, uses current consumer price indexes to convert nominal to real exchange rates, and is based to equal 1.0 in the first quarter of 1973.[7,8] The index series is quarterly; I use the four-quarter average index for each year in the sample.[9]

Results

Before analyzing industry-level investment sensitivity to GNP and real exchange rate movements, it is instructive to consider investment behavior in the aggregate. Let I_K_t be defined as the simple cross-sectional average investment rate in year *t*. Figure 1 contains a graph which plots the ratio of I_K_t to its mean (.132), the ratio of actual to potential GNP (A_PGNP_t), and the real, trade-weighted dollar

TABLE 1

Summary statistics, 1963-1986

Variable name	Label	All industries	Durable goods industries	Nondurable goods industries
Price-cost margin	PCM_{it}	.274 (.093)	.278 (.074)	.269 (.110)
Gross investment rate	I_K_{it}	.132 (.069)	.137 (.069)	.128 (.068)
Sales-capital ratio	S_K_{it}	5.11 (3.29)	4.44 (2.01)	5.82 (4.15)
Number of industries		270	140	130

NOTE: Standard deviations are in parentheses.

index, $R7GMA_t$, over the 1963-1986 time period. The investment rate clearly varies procyclically, and investment's variability appears to exceed that of output. The relationship between investment and the value of the dollar appears to be negative, at least after 1971 or so. This Figure suggests that, in the aggregate, investment does indeed vary procyclically and does increase when the dollar depreciates. The remainder of the article examines the data at the four-digit level.

Table 2 presents the results of estimating the relationship between investment rates (I_K_{it}), actual to potential GNP (A_PGNP_t), and the real value of the dollar ($R7GMA_t$) more formally:

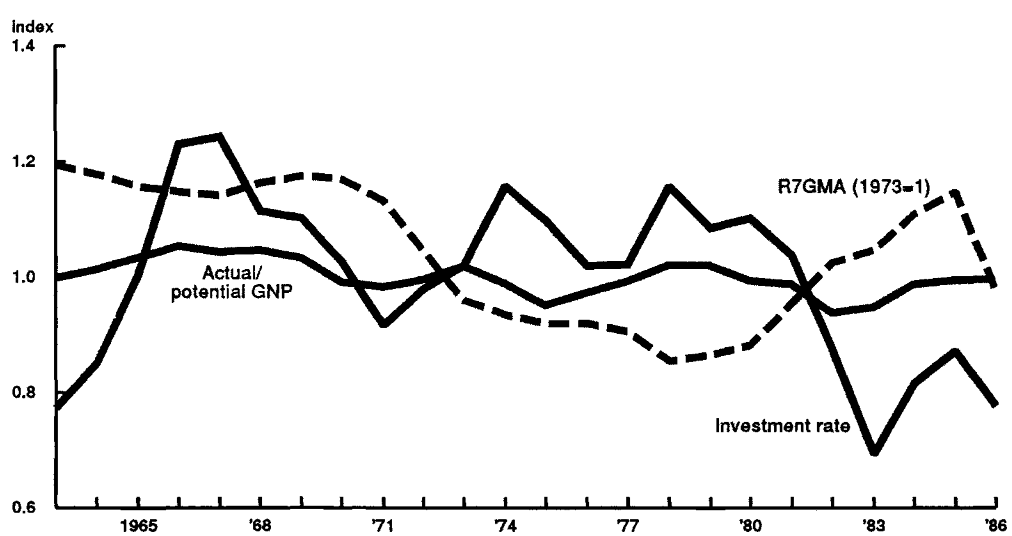
$$(2)\quad I\_K_{it} = \beta_0 + \beta_1 {*} A\_PGNP_t + \beta_2 {*} R7GMA_t + \varepsilon_{it},$$

where i denotes industry i, t denotes year t, and ε_{it} is an econometric error term. Because preliminary analysis suggested that the error term was serially correlated, I present both ordinary least squares (OLS) estimates and least squares estimates corrected for first order serial correlation, which are denoted as PW, for Prais-Winsten.[10] I present results for the full sample, for durable and nondurable goods industries separately, and for producer and consumer goods industries separately.

The OLS and PW results are qualitatively similar; I will discuss only the PW results.[11] The positive and significant coefficients on *A_PGNP* are interpreted as measuring the sensitivity of investment rates to changes in the strength of the macroeconomy. For the sample as a whole, a 1 percent increase in *A_PGNP* from its mean of 1.00 implies an increase of .00407 in the investment rate, or a 3.1 percent increase relative to the rate's mean of .132. These results conform with previous work by Petersen and

FIGURE 1

Investment, GNP, and real exchange rates



SOURCES: National Income and Product Accounts and the Federal Reserve Bank of Chicago.

TABLE 2

Investment rates, GNP, and real exchange rates
Dependent variable: I_K_{it}, 1963-1986

Coefficients:	CONSTANT	A_PGNP_t	$R7GMA_t$	R^2
All industries (270)				
OLS	$-.238^a$ (.029)	$.448^a$ (.029)	$-.076^a$ (.004)	.04
PW	$-.203^a$ (.029)	$.407^a$ (.030)	$-.072^a$ (.008)	-
Durable goods industries (140)				
OLS	$-.312^a$ (.040)	$.568^a$ (.041)	$-.117^a$ (.011)	.07
PW	$-.269^a$ (.040)	$.518^a$ (.041)	$-.111^a$ (.011)	-
Nondurable goods industries (130)				
OLS	$-.159^a$ (.041)	$.319^a$ (.043)	$-.033^a$ (.011)	.02
PW	$-.131^a$ (.042)	$.285^a$ (.043)	$-.030^b$ (.012)	-
Producer goods industries (196)				
OLS	$-.247^a$ (.034)	$.467^a$ (.036)	$-.086^a$ (.009)	.04
PW	$-.184^a$ (.034)	$.401^a$ (.035)	$-.085^a$ (.010)	-
Consumer goods industries (74)				
OLS	$-.217^a$ (.053)	$.398^a$ (.056)	$-.049^a$ (.014)	.03
PW	$-.255^a$ (.054)	$.424^a$ (.056)	$-.039^b$ (.015)	-

NOTES: I_K_{it} is the investment rate for industry *i* in year *t*, A_PGNP_t is the ratio of actual to potential GNP at time *t*, and $R7GMA_t$ is the real trade-weighted dollar index at time *t*. OLS refers to the ordinary least squares estimates, and PW refers to the Prais-Winsten estimates, which correct for first order serial correlation. Standard errors are in parentheses under coefficient estimates. Superscripts a, b, and c denote statistical significance at the 1 percent, 5 percent, and 10 percent level, respectively.

Strauss (1989, 1991), which concludes that investment is more cyclical, relative to its mean, than output.

The coefficients on *R7GMA* are significant and have the expected negative signs. Thus increases in the value of the dollar are associated with declines in investment rates in U.S. manufacturing. The magnitude of the effect suggests that investment is fairly responsive to changes in the value of the dollar. For the full sample, a 1 percent increase in *R7GMA* is associated with a decrease in the investment rate of .00075, or a .57 percent decrease relative to its mean.

Table 2 also confirms that investment patterns in durable goods industries differ from patterns in nondurable goods industries. Durable goods investment is more cyclical and more responsive to changes in real exchange rates than is nondurable goods investment. This difference is significant at the 1 percent level.

An alternative method of distinguishing broad groups of industries is to group them on the basis of the buyer's identity rather than the good type. Table 2 reports the results of estimating Equation (2) separately for producer goods and consumer goods industries.[12] Although the coefficient estimates do differ between the groups, an F test at conventional significance levels fails to reject the hypothesis that the coefficients do not differ. It appears, then, that the type of good produced (the durable goods/nondurable goods distinction) matters more than the identity of the customer (the producer goods/consumer goods distinction) in explaining investment patterns over this time period.

Previous researchers have documented substantial variation in output and input demand behavior at the two-digit SIC level, so in Table 3 I present the results of reestimating Equation (2) while allowing all coefficients to vary across two-digit groups.[13] The Table's results confirm that investment rates vary negatively with the value of the dollar and that this effect varies across two-digit groups. Consider first the coefficients on *A_PGNP*; most are positive, as expected. Thus investment is procyclical, and the degree of procyclicality varies across industries. Of the five two-digit groups with negative coefficients, only textiles (SIC 22) and rubber (SIC 30) have significant coefficients.

The coefficients on *R7GMA* are a bit more

TABLE 3

Industry investment rates, GNP, and real exchange rates
Dependent variable: I_K_{it}, 1963-1986

Industry	Prais-Winsten estimates CONSTANT	A_PGNP_t	$R7GMA_t$
20 Food	.158[a] (.011)	.066[b] (.032)	–.107[a] (.028)
21 Tobacco	.163[a] (.032)	.200[b] (.091)	–.236[a] (.078)
22 Textiles	.151[a] (.015)	–.115[a] (.043)	.066[c] (.037)
23 Clothing	.065[a] (.015)	.075[c] (.042)	–.005 (.037)
24 Lumber	.121[a] (.033)	.059 (.078)	–.055 (.067)
25 Furniture	.098[a] (.035)	.300[a] (.074)	–.216[a] (.057)
26 Paper	.142[a] (.026)	–.035 (.059)	.018 (.046)
27 Publishing	.126[a] (.026)	–.055 (.065)	.082 (.054)
28 Chemicals	.141[a] (.022)	.056 (.061)	–.074 (.048)
29 Petroleum refining	.108[a] (.035)	.458[a] (.084)	–.388[a] (.069)
30 Rubber	.240[a] (.040)	–.300[a] (.086)	.142[b] (.070)
31 Leather	.100 (.069)	.142 (.166)	–.124 (.111)
32 Stone, clay, glass	.065[a] (.012)	.243[a] (.029)	–.177[a] (.025)
33 Primary metals	.098[a] (.016)	.083[c] (.046)	–.055 (.039)
34 Metal products	.110[a] (.016)	.202[a] (.043)	–.167[a] (.036)
35 Industrial equipment	.155[a] (.012)	.127[a] (.035)	–.146[a] (.031)
36 Electronic equipment	.122[a] (.015)	.187[a] (.040)	–.145[a] (.034)
37 Transportation equipment	.149[a] (.020)	.101c (.055)	–.104[b] (.049)
38 Instruments	.245[a] (.040)	–.126 (.137)	–.007 (.098)
39 Miscellaneous	.163[a] (.038)	.014 (.078)	–.050 (.057)

Notes: I_K_{it} is the investment rate for industry *i* in year *t*, A_PGNP_t is the ratio of actual to potential GNP at time *t*, and $R7GMA_t$ is the real trade-weighted dollar index at time *t*. The table reports the results of the PW regression of *I_K* on *A_PGNP* and *R7GMA*, while permitting all coefficients to vary over two-digit SIC groups. Reported coefficients are the total effect for the given two-digit group. Standard errors are in parentheses under coefficient estimates. Superscripts a, b, and c denote statistical significance at the 1 percent, 5 percent and 10 percent level, respectively.

varied in sign and magnitude. For 16 of the 20 two-digit groups, *R7GMA* enters with a negative sign, as expected; 9 of these 16 coefficients differ significantly from 0. The coefficients are largest for two-digit groups 29 (petroleum), 21 (tobacco), 25 (furniture), 32 (stone, clay, and glass), and 34 (metal products).[14] These results appear generally consistent with those of Branson and Love (1988), who find that the real exchange rate has its greatest effects on employment in the two digit groups 33 (primary metal), 35 (industrial equipment), 34, 29, 32, and 39 (miscellaneous).[15] Again, textiles and rubber are the only groups whose coefficients are significant and the wrong sign. The textiles industry enjoyed substantial import protection during the time period covered by this study, so the industry's investment spending may not have been likely to respond in the expected way to the appreciation of the dollar.

Finally, as indicated earlier, it is likely that an industry's exposure to international markets influences the size of its investment responsiveness to exchange rate changes. One measure of that exposure, the industry import-sales (*IMS*) ratio, is available for 173 of the sample's 270 industries over the 1965-1980 time period. Because of this limited availability, I computed each industry's average *IMS* over the available time period and then grouped industries into high *IMS* and low *IMS* industries, comparing industry averages to the overall average. I then re-estimated Equation (2) over the 173-industry sample and separately over the high and low *IMS* industries, respectively.[16] The results appear in Table 4. In brief, the coefficient on *R7GMA* is larger in the high *IMS* industries, and an

F test rejects the null hypothesis of pooling of high and low *IMS* industries, showing that this difference is statistically significant. So, higher *IMS* ratios are associated with larger investment responses to exchange rate fluctuations. This is reasonable, because industries experiencing substantial foreign competition at home are likely to be sensitive to exchange rate fluctuations.

TABLE 4

Investment rates and real exchange rates
Dependent variable: I_K_{it}, 1963-1986

Coefficients:	CONSTANT	A_PGNP_t	$R7GMA_t$	R^2
All industries with IMS data (173)				
OLS	$-.165^a$ (.036)	$.373^a$ (.038)	$-.078^a$ (.010)	.03
PW	$-.119^a$ (.037)	$.326^a$ (.038)	$-.080^a$ (.010)	-
High IMS industries (49)				
OLS	−.094 (.075)	$.322^a$ (.079)	$-.102^a$ (.020)	.03
PW	−.074 (.081)	$.303^a$ (.083)	$-.101^a$ (.023)	-
Low IMS industries (124)				
OLS	$-.193^a$ (.041)	$.393^a$ (.043)	$-.069^a$ (.011)	.03
PW	$-.138^a$ (.041)	$.337^a$ (.041)	$-.071^a$ (.012)	-

NOTES: I_K_{it} is the investment rate for industry *i* in year *t*, *IMS* is the import-sales ratio, A_PGNP_t is the ratio of actual to potential GNP at time *t*, and $R7GMA_t$ is the real trade-weighted dollar index at time *t*. OLS refers to the ordinary least squares estimates, and PW refers to the Prais-Winsten estimates, which correct for first order serial correlation. Standard errors are in parentheses under coefficient estimates. Superscripts a, b, and c denote statistical significance at the 1 percent, 5 percent, and 10 percent level, respectively.

Summary and conclusions

In this article, I presented evidence that fixed investment rates are sensitive to changes in the value of the dollar. Investment responds more in durable goods industries than in nondurable goods industries, but there appears to be little difference between consumer goods and producer goods industries. Further, investment is more sensitive to exchange rate fluctuations for industries experiencing substantial foreign competition.

Some readers may be surprised at investment's responsiveness to relative price changes, given the limited role for relative factor prices in much recent research on investment spending. To what extent might industries absorb exchange rate fluctuations into their price-cost margins (PCMs) instead of their input demands? In fact, in a related, unpublished analysis of industry PCMs, I found that this price adjustment effect is present in the data: when the dollar appreciates, domestic PCMs fall, especially so in durable goods industries. So it appears that as the relative price of domestic goods changes, U.S. industries respond by changing both the price and quantity of output (hence inputs like capital). Developing structural models that can distinguish these two sets of exchange rate effects is an important area for future research.

Finally, although my results should be viewed as suggestive only, they do indicate the potential importance of exchange rate movements for the future international competitiveness of U.S. manufacturing industries. The highly valued dollar of the 1980s may have led to some long run deterioration in the ability of U.S. industries to compete in international markets. Between 1978 and 1985, the dollar index rose from .856 to 1.149, an appreciation of 34 percent. Table 2's coefficient estimates imply that the average industry's investment rate was .021 lower in 1985 than it would have been in the absence of the dollar's appreciation. The raw investment data for the sample show that total investment spending in 1985 was $61.8 billion. Combining this figure with appropriate capital stock figures and Table 2's estimates, I estimate that investment spending in 1985 was $11.3 billion less than it would have been had the dollar not appreciated. The decline in the dollar in recent years, though not examined directly in this article, may have reversed this trend, thus enabling U.S. industries to effectively compete at home and abroad.

FOOTNOTES

[1]Note that strict application of the "purchasing power parity" argument implies that $e = 1$, that is, that changes in E are simultaneously offset by changes in relative prices. Consequently, for these arguments to be correct, some sort of price stickiness must prevent parity from being reached.

[2]In other words, I estimate a "reduced form" relationship between investment and real exchange rates. For an example of analysis of a structural relationship between input demands and real exchange rates, see Krieger (1989), who argues that real exchange rate changes affect factor demands through two channels. The first is the one discussed above: an increase in the value of the dollar causes an increase in the relative price of U.S. goods, thus a decrease in aggregate derived factor demands. The second channel involves the sectoral reallocation of resources that follows an exchange rate shock, regardless of whether the shock is positive or negative. The two channels are not mutually exclusive, and distinguishing between the two requires a structural model.

[3]For example, see Branson and Love (1988) and Krieger (1989).

[4]The SIC system assigns all manufacturing establishments into categories based on the primary activities at the establishments, and its most often used categories are the two- and four-digit groupings. Two-digit numbers are used to denote major groups, such as SIC 20, which is Food and Kindred Products, while four-digit numbers correspond to more narrowly defined categories, such as SIC 2011, which is Meat Packing Plants.

[5]Industries in two-digit SIC groups 24, 25, or 32-38 were labeled durable goods industries; others were placed in the nondurables group. See Petersen and Strauss (1991).

[6]For each of the three variables reported in Table 1, I can reject at the 5 percent level the hypothesis that the mean is the same for durable and nondurable goods industries.

[7]Using versions of the index based on lagged (as opposed to current) prices led to results similar to those reported below.

[8]See Hervey and Strauss (1987a) for a discussion of the appropriate price index to use when constructing a real exchange rate. Branson and Love (1988) report that using producer price indexes or more general price indexes made little difference to their ranking of industries in terms of their output and employment elasticities with respect to the real exchange rate.

[9]Using fourth quarter values made no qualitative and minor quantitative difference to the analysis.

[10]See Judge et al. (1985), p. 286. Ordinary least squares (OLS) estimation is appropriate under the following assumptions:

(3a) $E(\varepsilon_{it}) = 0$,

(3b) $E(\varepsilon_{it}^2) = \sigma_\varepsilon^2$,

(3c) $E(\varepsilon_{it}\varepsilon_{jt}) = 0$ for $i \neq j$, and

(3d) $E(\varepsilon_{it}\varepsilon_{is}) = 0$ for $t \neq s$.

Preliminary analysis suggested that first order serial correlation was significant and that the autoregressive parameter differed across four-digit industries, so I permitted the parameter to vary in the estimation. This amounts to replacing assumption (3d) by $E(\varepsilon_{it}\varepsilon_{is}) = \rho_i$, so that ε_{it} is assumed to follow the autoregressive process

$$\varepsilon_{it} = \rho_i \varepsilon_{it-1} + u_{it},$$

where I assume that u_{it} is a mean zero, variance σ_u^2 random variable with no serial or contemporaneous correlation.

[11]The reader will notice the low R^2 values in the Table. Low R^2s are common in pooled time-series cross-sectional analyses. Estimating a pure time series version of (2), so that the dependent variable is I_K_t, yields an R^2 of .47, with coefficient estimates identical to those in the first line of Table 2. The Durbin-Watson statistic is .98.

[12]The classification is taken from DHP (1987).

[13]Only the Prais-Winsten estimates are presented. Specifications that restricted all slope coefficients to be equal across two-digit groups were rejected by F tests at the 1 percent level. Further, specifications that restricted the coefficients on *A_PGNP (R7GMA)* while permitting those on *R7GMA (A_PGNP)* to vary were also rejected.

[14]It is possible to compute an elasticity of the investment rate with respect to the dollar index, but the measure is difficult to interpret. I choose to focus on the absolute coefficient estimates themselves.

[15]Branson and Love (1988) obtain similar results when analyzing industrial production's response to real exchange rate changes.

[16]This procedure is strictly appropriate only if the variable used to group industries, here the IMS ratio, is exogenous.

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