NBER WORKING PAPER SERIES

SYSTEMATIC MOVEMENTS IN REAL EXCHANGE RATES IN THE G-5: EVIDENCE ON THE INTEGRATION OF INTERNAL AND EXTERNAL MARKETS

Richard C. Marston

Working Paper No. 3332

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
April 1990

I would like to thank Bernard Dumas and Jerome Stein for their helpful comments on an earlier draft. This paper is part of NBER's research program in International Studies. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

NBER Working Paper #3332
April 1990

SYSTEMATIC MOVEMENTS IN REAL EXCHANGE RATES IN THE G-5: EVIDENCE ON THE INTEGRATION OF INTERNAL AND EXTERNAL MARKETS

ABSTRACT

Many recent studies have documented the random behavior of real exchange rates. This paper shows that real exchange rates defined for different sectors of an economy move closely together with one another even though each of the sectoral real exchange rates taken alone has a large random component. The sectoral real exchange rates are tied together by internal price links due to factor mobility within each national economy. Any differences between real exchange rates which develop, moreover, can be explained almost entirely by productivity differentials, at least in the long run. This paper contrasts the strong ties which bind together prices from different sectors internally with ties that bind the prices of goods from the same sector internationally. Prices are shown to be much more highly correlated internally than externally because flexible exchange rates disrupt normal pricing relationships between goods from different countries.

Richard C. Marston
Wharton School
University of Pennsylvania
Philadelphia, PA 19104

Since 1973 when exchange rates for the major industrial countries first became flexible, evidence on the randomness of real exchange rates has accumulated steadily. The randomness arises because nominal exchange rates respond more flexibly to economic disturbances than do the prices of the goods themselves. Some studies such as Adler and Lehmann (1983) and Roll (1979) have even hypothesized that real exchange rates follow a random walk without being influenced by fundamental factors of demand and supply. Other more recent studies such as those by Frankel (1985) and by Abuaf and Jorion (1989) have been able to reject the random walk hypothesis, but even these studies have shown that real exchange rate movements have considerable persistence, with barely discernible tendencies to revert toward any equilibrium values. All of these studies have concurred in the view that most movements in real exchange rates are random. Nominal exchange rate flexibility thus has introduced randomness to the relative prices of goods from different countries.

This paper aims to provide a fresh perspective on these findings by contrasting them with relative price movements internal to national economies. The paper shows that prices of different goods within a single national economy are more closely linked than prices of similar if not identical goods originating in different economies.

The starting point for this investigation is a comparison of real exchange rate movements involving different sets of goods. Since Balassa's (1964) study of purchasing power parity, it has been known that aggregate and sectoral real exchange rates can diverge if productivity growth is faster in the traded sector than it is in the nontraded sector.[1] The first section of this paper develops evidence on the movement of real exchange rates in the Group of Five (or G-5) industrial countries, France, Germany, Japan, the United States and the United Kingdom. This section compares real exchange rates based on economy-wide prices and prices in the manufacturing sector. It shows that the differences between these real exchange rates are not random, but are instead almost fully explainable by patterns of productivity growth. The paper then develops analagous evidence for real exchange rates defined for subsectors of manufacturing such as transport equipment or electrical machinery. The relative movements in real exchange rates are systematically related to productivity growth patterns across manufacturing. Real exchange rates defined for different sets of goods, in fact, appear to

---

[1] Balassa focused on productivity growth as a cause of deviations from purchasing power parity. The more recent literature cited above has divided on whether there is any tendency for PPP to hold. (If real exchange rates follow a random walk with no mean reversion tendencies, then PPP cannot hold even in the long run). More recent studies of deviations from PPP include Hsieh (1982) and Marston (1985).

move in "lockstep" with one another, with their relative movements being systematically related to productivity differentials, even though all of these exchange rates have (common) random elements.

The third section of the paper interprets this pattern of real exchange rate behavior in terms of the relative integration of national and international markets. One would expect prices of goods from an individual industry to follow more closely prices from the same industry in other countries than prices from other industries in that country. Yet the randomness of real exchange rates at both the aggregate and sectoral levels suggests otherwise. This section shows that the relative movements of sectoral real exchange rates provide evidence on how well integrated are national rather than international markets. These sectoral movements indicate that national factor markets tie together the prices of dissimilar products more effectively than do the goods markets at the international level. The section then explicitly compares the degree to which national and international prices are correlated. The conclusion is that national prices are almost uniformly more closely linked than are prices internationally even though the national prices are from different industries. This conclusion is based on evidence from annual time series for value added deflators as well as monthly time series for producer price indexes.

I. Systematic Movements in Real Exchange Rates

Real exchange rates can be defined for the economy as a whole or for the manufacturing or another individual sector alone. At one extreme, the real exchange rate might be based on broad-based indexes such as the consumer price index (CPI), wholesale price index (WPI), or GDP deflator. But if the competitiveness of the traded sector is of interest, the real exchange rate should be defined in terms of prices in that sector alone.

A. Real Exchange Rates for Manufacturing

In the case of the G-5 countries, manufactures constitute the bulk of traded goods, so it makes sense to define the real exchange rate in terms of manufacturing prices.[2] The real exchange rate for traded goods thus might be defined in terms of the wholesale price index in manufacturing or the value added deflator in manufacturing. The latter are used here for two reasons. First, value added deflators for manufacturing are available for all G-5 countries, and sectoral value added deflators, which are studied later in the paper, are available for the same sectors of manufacturing as the productivity data.[3] Second, because they measure value added, the deflators are not directly affected by movements in the prices of raw materials and fuel, two prices which varied widely in the 1970s. The series

2 Agricultural goods are also important traded goods, but their prices are distorted by numerous subsidies. Similarly, oil and other energy prices are distorted by OPEC's actions as well as by national energy policies.

3 A wholesale price index for manufacturing goods is not available for France. In addition, sectoral wholesale price indexes are available on a consistent basis for only three of the five countries.

used are the GDP deflator (for the whole economy) and the value added deflator for manufacturing alone.

Throughout the paper, real exchange rates are defined as the ratio of U.S. prices to foreign prices, both expressed in a common currency. All non-U.S. variables are starred, and all exchange rates are measured as foreign currency per $. All variables are expressed in logarithms. The price and exchange rate series are defined as follows:

P (P^*): GDP deflator for the U.S. (foreign country),

P_m (P_m^*): value added deflator for U.S. (foreign) manufacturing,

S: foreign currency/$.

The real exchange rates defined for the whole economy and for manufacturing alone are as follows:

(1) $R = P + S - P^*$,

(2) $R_m = P_m + S - P_m^*$.

A rise in either of these real exchange rates represents a <u>real depreciation</u> of the foreign currency and a loss of competitiveness for the United States.

Table 1 below presents changes in the real exchange rate between 1973 and 1986, measured as changes in the logarithms of R and R_m defined above. The table shows the two series for the real exchange rate behaved quite differently over the 1973-86 period. In the case of the series based on the value added deflator for manufacturing, the dollar depreciated in real terms (i.e., the real exchange rate fell) vis-a-vis all four currencies. But in the case of the GDP deflator, the dollar

Table 1
Average Changes in Real Exchange Rates, 1973-86
(U.S. Relative to Foreign Prices)

Country	GDP Deflator	VA Deflator In Manuf.	Excess in Manuf.
Japan	- 2.0 %	- 0.4 %	1.6 %
France	0.5 %	- 0.4 %	- 0.9 %
Germany	0.8 %	- 0.5 %	- 1.3 %
U.K.	- 0.8 %	- 2.0 %	- 1.2 %

Sources: Eurostats, National Accounts ESA; OECD, National Accounts.

appreciated relative to the franc and mark.

Which real exchange rate series is preferable depends on the context. If one is interested in measuring the relative competitiveness of the manufacturing sector, then using a broader based price index can be misleading. In the case of Japan, the real exchange rate based on the GDP deflator is biased downward, meaning that Japan appears to be losing more competitiveness (vis-a-vis the United States) than it actually is. In the case of all three European countries, the real exchange rate based on the GDP deflator is biased upward, meaning that these countries appear to be gaining more competitiveness than they actually are.

B. Real Exchange Rates and Productivity Growth

These biases can be explained almost fully by patterns of productivity growth among the G-5 countries. Labor productivity for the economy as a whole can be defined (in logs) as follows:

(3) $H = V - L$, where

V: GDP (i.e., value added in real terms),

L: employment.

In the tables below, productivity is measured as an average percentage change between 1973 and 1986. Changes in productivity, in turn, can be traced to two sources: capital deepening (measured by the growth in the capital-labor ratio) and technical progress.[4] Table 2 below reports figures for productivity growth for the whole economy and manufacturing sector of each G-5 country. The underlying data are drawn from the national accounts for the period from 1973 to 1986 (1985 for France and Germany).

The table has two notable features: (a) In all five countries, productivity growth is greater in the manufacturing sector than in the economy as a whole. The gap between productivity growth rates is greatest in Japan and the United States (2.8 % and 1.9 % per annum, respectively), but it is sizable in every country. (b) The three European countries have very similar productivity growth differentials (0.6 % for Germany and 0.7 % for France and the United Kingdom). France and

---

[4] If the economy is characterized by a Cobb-Douglas production function, then

$$V - L = c_1 (K - L) + h t, \text{ where}$$

the coefficient c_1 can be defined as capital's share in GDP and h as the rate of technical progress. If the production function is CES, then the expression above must be regarded as a linear approximation of the original production function. See Marston and Turnovsky (1985).

Table 2.
Average Productivity Growth, 1973-86

	Whole Economy	Manufac turing	Excess in Manuf.
U.S.	0.6 %	2.5 %	1.9 %
Japan	2.3 %	5.0 %	2.8 %
France	2.2 %	2.9 %	0.7 %
Germany	2.2 %	2.8 %	0.6 %
U.K.	1.6 %	2.3 %	0.7 %

Sources: same as Table 1. For France and Germany, the figures for productivity growth are for 1973-85 only.

Germany, moreover, have identical productivity growth rates in the whole economy (2.2 %) and almost identical growth rates in manufacturing (2.9 % and 2.8 %). As explained below, the similarity between their productivity growth rates helps to explain why their real exchange rates have stayed so closely in line.

The link between productivity growth and real exchange rates is through unit labor costs and prices. The value added deflator is related to productivity through the following markup equation:

(4) $P = W - H + M$, where

W: the wage,

M: the markup of prices over marginal cost.

If similar expressions are used for the value added deflator in the manufacturing sector and deflators in the foreign country, then the two real exchange rates can be related to productivity growth differentials as follows:

$$(5)\quad R_m - R = -[(H_m - H) - (H_m^* - H^*)] + [(W_m - W) - (W_m^* - W^*)] + [(M_m - M) - (M_m^* - M^*)].$$

This equation states that if the United States has a greater productivity growth differential between manufacturing and the whole economy than does its trading partners, then the real exchange rate based on the value added deflator for manufacturing will have to <u>fall</u> through time relative to that based on the GDP deflator. Real exchange rates are also influenced by two other factors: Differences in wage rates between sectors of each economy could also lead to differences in real exchange rates, but the average <u>growth</u> in wage rates is likely to be very similar in manufacturing as in the economy as a whole. Similarly, differences in markups could lead to differences in real exchange rates, but there is unlikely to be a pronounced difference in the average <u>growth</u> of the markups between sectors. So the link between real exchange rates and productivity growth should be a close one, at least in the long run.

That link is borne out in the figures in Table 3. The table reports the sectoral bias in real exchange rates, defined as the difference between the real exchange rate based on the value added deflator for manufacturing and that based on the GDP deflator: $R_m - R$, where the variables are expressed as average percentage changes. The table also reports the relative gaps in productivity growth in the United States and the corresponding

Table 3. Differentials in the Growth of
Sectoral Real Exchange Rates and Productivity, 1973-86

	Differentials in Growth of Real Exchange Rates	Differentials in Relative Productivity Growth
Japan	1.6 %	- 0.8 %
France	- 0.9 %	1.1 %
Germany	- 1.3 %	1.2 %
U.K.	- 1.2 %	1.2 %

Note: Same sources as Table 1. For France and Germany, the figures for productivity growth are for 1973-85 only.

foreign country: $(H_m - H) - (H_m^* - H^*)$.

The table reveals a remarkably close correspondence between the sectoral bias in real exchange rates and the sectoral bias in productivity growth. The two biases are of the opposite sign in each country and are almost identical in absolute size except in the case of Japan.

The interpretation of these figures is quite instructive. In the case of Japan, the bias in productivity growth toward manufacturing is greater in Japan than in the United States. That is, $(H_m^J - H^J) > (H_m^{US} - H^{US})$, where the variables are expressed as percentage changes. And the bias in real exchange rate changes is positive because the real exchange rate based on the GDP deflator has fallen more than that based on manufacturing prices: $R < R_m < 0$. Higher productivity growth in the manufacturing sector of Japan allows it to reduce the price of manufactures relative to other goods through time. So the real appreciation of the yen which has occurred since 1973 is larger in terms of the GDP deflator than in terms of the manufacturing deflator alone. This makes the appreciation of the yen seem larger than it is in reality, since it is manufactured goods, not the GDP as a whole, which Japan exports.

In the case of the three European countries, the bias is in the opposite direction. The bias in productivity growth in the manufacturing sector is greater in the United States than it is in the European countries. And the bias in real exchange rates is negative, with the real exchange rate based on the manufacturing deflator falling relative to that based on the GDP deflator. Relatively higher productivity growth in the U.S. manufacturing sector allows it to reduce the relative prices of manufacturing goods more than in Europe. So the real appreciation of the European currencies in terms of manufacturing prices is larger than the appreciation in terms of the GDP deflator. The franc and mark, in fact, have depreciated relative to the dollar in terms of the GDP deflator at the same time that they have appreciated in terms of manufacturing prices alone. Thus for all G-5 countries, measuring competitiveness in terms of broad-based prices can be seriously misleading. But in all cases the bias is systematically related to patterns of productivity growth.

II. Changes in Sectoral Real Exchange Rates

In this section we consider prices at the sectoral level in manufacturing. Over periods as long as the thirteen years considered in this study, prices in one sector vary substantially relative to those in other sectors. Thus to understand how the competitiveness of a country is changing, it is important to look beyond average price performance in manufacturing to examine sectoral price performance.

A. Sectoral Real Exchange Rates and Productivity Differentials

Real exchange rates can be defined for sectors of manufacturing such as transport equipment or electrical machinery by relating the U.S. value added deflator for that sector to the deflator in a second country also expressed in dollars. Thus the real exchange rate for sector i is defined as follows:

(6) $R_i = P_i + S - P_i^*$, where

P_i is the value added deflator for sector i in the United States, and

P_i^* is the value added deflator for sector i in the foreign country.

Just as there are systematic changes in real exchange rates in manufacturing relative to the rest of the economy, real exchange rates at the sectoral level vary systematically relative to real exchange rates in manufacturing as a whole.

The top part of Figure 1 illustrates how large are some of the changes in real exchange rates at the sectoral level. This figure shows sectoral real exchange rates for the manufacturing sectors in the United States and Japan. Table 4 lists the eleven manufacturing sectors involved.[5] The real exchange rates are defined as the relative price of the U.S. good to the Japanese good, both expressed in dollars. At the extreme left of the figure is the change in the real exchange rate for manufacturing as a whole. While the change in this real exchange rate is quite small, many sectors of manufacturing have experienced rather large changes in real exchange rates. These range from a five percent fall in the real exchange rate in sector 1 to an eight percent rise in the real exchange rate in sector 10. It is evident that the change in real exchange rates for manufacturing as a whole masks a large amount of real exchange rate variation at the sectoral level.

As explained above, the movement in the real exchange rate for any sector of the economy as well as for the economy as a whole is governed by macroeconomic forces. If the sample period had ended in 1984, the slight fall in the real exchange rate for manufacturing would have been replaced by a substantial increase since the nominal yen-dollar exchange rate (which began falling in early 1985) has a major effect on all real exchange rates between the yen and dollar. But the relative movement in real exchange rates from one sector to another is a phenomenon which can be explained by microeonomic factors such as relative

---

[5] The twenty-two U.S. categories appearing in the U.S. Department of Commerce, Survey of Current Business were combined into the same thirteen categories appearing in the Government of Japan, Economic Planning Agency, Annual Report on National Accounts. The list omits petroleum and coal products as well as the miscellaneous category in the Japanese national accounts.

Table 4. List of Manufacturing Sectors

Number	Sector
1	Food and Beverages
2	Textiles
3	Pulp, Paper, and Paper Products
4	Chemicals
5	Non-Metallic Mineral Products
6	Basic Metals
7	Fabricated Metal Products
8	General Machinery
9	Transport Equipment
10	Electrical Machinery and Equipment
11	Precision Instruments

Note: The definitions of these sectors vary somewhat from one country to another. In the three European countries, Sector 11 includes business machinery in addition to precision instruments.

Sources for Data: For U.S. data, U.S. Department of Commerce, Survey of Current Business; for Japanese data, Government of Japan, Economic Planning Agency, Annual Report on National Accounts; for French, German, and U.K. data, Eurostat, National Accounts ESA.

productivity growth.

The sectoral real exchange rates are systematically related to sectoral productivity growth differentials just as their aggregate counterparts are related. Figure 1 illustrates the close link between real exchange rates and productivity growth differentials in the case of the United States and Japan. The lower half of the figure shows productivity growth by sector for both countries. In the manufacturing sector as a whole (at the extreme left of the graph), Japan has productivity growth of five percent compared with growth in the United States of a little over two percent. But in individual sectors, productivity growth varies widely. In sector 1, food and beverages, the U.S. has a substantial productivity growth advantage. This advantage is reflected in a fall in the sectoral real exchange rate by about five percent per annum.[6] At the other extreme in sector 10, electrical machinery and equipment, Japan has an even more substantial productivity growth advantage than the United States did in sector 1. As a result, the sectoral real exchange rate has risen by over eight percent per annum.

To see the link between real exchange rates and productivity growth at the sectoral level, compare the real exchange rate in sector i to the real exchange rate in the entire manufacturing sector. The value added deflator for sector i is related to wages, productivity, and the markup in that sector as follows:

$$(7) \qquad P_i = W_i - H_i + M_i.$$

If a similar expression is used to explain value added deflators in the foreign country, then the two real exchange rates can be related to productivity growth differentials as follows:

$$(8) \quad R_i - R_m = -[(H_i - H_m) - (H_i^* - H_m^*)] + [(W_i - W_m) - (W_i^* - W_m^*)] + [(M_i - M_m) - (M_i^* - M_m^*)].$$

The difference in real exchange rates is related to three factors: the differential growth in productivity between sector i and manufacturing, the differential growth in wages, and the

---

6 Thus the real exchange rate in sector 1 has fallen about five percent more than in manufacturing as a whole. It is the <u>difference</u> in these changes in real exchange rates that can be explained by productivity growth patterns.

differential growth in markups. This equation states that if the United States has relatively higher productivity growth in sector i than does the foreign country, then, ceteris paribus, the real exchange rate for that sector will fall (i.e., the U.S. price in that sector will fall relative to the foreign price). Alternatively, if the United States experiences greater wage growth or greater increases in markups in sector i than does the foreign country, then the real exchange rate in that sector will rise rather than fall.

From one year to another, the growth in markups might vary in one sector relative to another as demand and cost conditions change. Similarly, wage growth might vary in one sector to another in the short run. But over a thirteen year period, the average growth in markups is unlikely to be very different in one sector than another, at least if investment is free to respond to relative profit incentives. And the average growth in wages in one sector is unlikely to be very different from wage growth in another sector, as long as labor is free to move among sectors in response to relative wage changes. So in equation (8), the principal determinant of changes in real exchange rates should be productivity growth differentials.

B. <u>Cross Section Evidence</u>

To investigate equation (8) empirically, we took average percentage changes in real exchange rates ($\bar{R}_i$) and productivity growth ($\bar{H}_i$) over the period from 1973 to 1986. We then estimated a cross section equation of the form:

$$(9) \quad \bar{R}_i - \bar{R}_m = a + b [(\bar{H}_i - \bar{H}_m) - (\bar{H}^*_i - \bar{H}^*_m)] + U_i.$$

In each case, the average change in the real exchange rate in manufacturing was subtracted from the average change in sector i. And the differential between average productivity growth in the United States and the foreign country in manufacturing was subtracted from the corresponding differential in sector i.

Table 5.

Real Exchange Rate Changes in Sector i Relative to Manufacturing[a]
1973-86

Countries Compared	Productivity Growth Differentials	Constant	$\bar{R}^2$ (SEE)
U.S. - Japan	-0.844	0.004	.867
	(0.102)	(0.004)	(.014)
U.S. - France	-1.181	0.000	.760
	(0.207)	(0.003)	(0.011)
U.S. - Germany	-1.244	0.002	.727
	(0.237)	(0.003)	(0.011)
U.S. - U.K.[b]	-0.857	-0.001	.909
	(0.085)	(0.003)	(0.010)
France-Germany	-0.714	0.001	.339
	(0.288)	(0.002)	(0.008)

Notes: [a] Standard errors are in parentheses below the coefficients.

[b] The equation for the United Kingdom begins in 1975 because the national accounts data disaggregated by manufacturing sector begin in that year.

Sources: same as Table 4.

Table 5 reports equations estimated over the cross section of eleven sectors of manufacturing. In the first four equations, the United States is compared with other G-5 countries, while in the last equation France is compared with its closest trading partner, Germany. The equations reveal that there is a close link between changes in real exchange rates and productivity growth differentials. In each equation, the coefficient of the productivity growth term is insignificantly different from minus one at the five percent level. Productivity growth differentials alone are able to explain a large proportion of the variation in real exchange rates across sectors. The close link revealed in Figure 1 for the United States and Japan is evidently also found in comparisons with other G-5 countries. Before considering these results in more detail, we examine the equation estimated for real exchange rates between France and Germany.

C. Real Exchange Rate Movements Between France and Germany

The last equation of Table 5 reports on real exchange rate movements between France and Germany. The equation explains a relatively small proportion of the cross section variance in real exchange rates. In fact, there is little cross section variation to be explained in the case of these two countries. Consider Figure 2 which shows the average changes in real exchange rates and productivity growth by sector for France and Germany. The scales of the two graphs in the figure are the same as used in the U.S.-Japan figure shown previously. It is apparent from the upper half of this diagram that the real exchange rate movements are much smaller than in the case of the United States and Japan.

This section examines these movements more closely.

One might be tempted to attribute the behavior of these real exchange rates to exchange rate arrangements within Europe. France and Germany have limited changes in their bilateral exchange rates through successive exchange rate agreements beginning with the Snake in 1973 and continuing with the European Monetary System (or EMS) from 1979 to present. These agreements have not prevented all nominal exchange rate adjustments, but have certainly limited them compared with adjustments in the dollar relative to the franc and mark. So the prices of French and German products in the currency of the trading partner have been stabilized. As shown in Table 6, the variances of prices in French and German manufacturing are far smaller in local currency than in either foreign currency. But the variances of these prices are also considerably smaller in the partner's currency than in dollars. For example, the variance of French prices is much smaller when these prices are expressed in marks rather than

Table 6
Variances of European Prices in Local and Foreign Currencies
Manufacturing Prices, 1973-86

	Prices in Currency:		
	FF	DM	$
France	0.0003	0.0033	0.0176
Germany	0.0032	0.0003	0.0180

Sources: Same as those of earlier tables.

dollars. This means that the variance of the real exchange rates between France and Germany is also quite smaller than between either country and the United States.

Yet there is more to the explanation than exchange rate arrangements alone. The upper graph shows that not only have real exchange rates on average been fairly stable in Europe, but also that there has been very little variation in real exchange rate changes <u>across</u> sectors of manufacturing.[7] The largest increases in rates are about 1 percent and the largest declines are a little over 1 percent. This is in sharp contrast to the experience of Japan and the United States where changes range from - 5 percent to + 8 percent.

Why has there been so little variation in real exchange rates across sectors in France and Germany? A major reason must be that productivity growth differentials were remarkably similar across sectors. Consider the lower half of Figure 2 which shows average productivity growth by sector for France and Germany. In contrast to the earlier comparison of the United States and Japan, here the differences in productivity growth are small across sectors. So there is relatively little need for real exchange rates to adjust more in one sector than another. France and Germany appear to be sufficiently similar in productivity growth sector by sector so as to limit adjustments in real

---

[7] In the case of real exchange rates for manufacturing as a whole, the change over the 1973-86 period is almost as small for the United States vs. Japan as for France vs. Germany. So what is different about the two figures is the variation in real exhange rate performance across manufacturing sectors.

exchange rates from one sector to another. This phenonmenon may be a fortunate coincidence -- fortunate because it reduces the need for structural adjustment between the two economies. Or this phenomenon may reflect the integration of European industry due to the European Economic Community. Increasing integration between France and Germany may be bringing convergence in productivity growth patterns by industry.

III. The Integration of Internal and External Markets

The systematic link between real exchange rates and productivity growth revealed in Table 5 may be puzzling in light of the evidence presented on the random nature of real exchange rates. How is it possible that the real exchange rate series here are related so systematically to productivity growth differentials? The key difference here is that we have examined one real exchange rate relative to another real exchange rate rather than a single real exchange rate by itself. It may be true that the real exchange rate in sector i is a random variable because the nominal exchange rate is itself random. But the same randomness is found in sector j or in manufacturing as a whole, so the differential movement in real exchange rates between two sectors may not be random.

A. Internal Price Adjustment

In fact, the elements that tie together real exchange rates in one sector to those in another are largely internal rather than external in nature. It is labor and capital mobility within national economies that ensures that equation (8) above holds at least as a long term average. Consider the following equation linking the average growth rate in internal prices to average productivity growth differentials in a single country:

$$(10) \qquad \bar{P}_i - \bar{P}_m = c + f(\bar{H}_i - \bar{H}_m) + v_i,$$

where v_i is a random variable. The coefficient f should be equal to negative one and all remaining variation in relative prices should be random under two conditions: if wage growth in sector i approximates that in manufacturing as a whole and if the growth in markups in sector i approximates that in manufacturing. Internal labor mobility should ensure that average wage growth is similar across the manufacturing sector, over long periods of time at least. And internal capital mobility should ensure that the growth in markups is similar across manufacturing.

Table 7 reports the results of estimating equation (10) across the eleven sectors of manufacturing. The results are very similar to those for real exchange rates in Table 5. For each country except Japan, the coefficient of the productivity growth term is insignificantly different from minus one at the five percent level. And even in the case of Japan, the coefficient is close to minus one. So it is clear that the behavior of real exchange rates exhibited in Table 5 is largely a reflection of internal price adjustment. In effect, random movements in the nominal exchange rate can lead to random movements in real exchange rates between any two countries. But the whole range of sectoral real exchange rates for these two countries will move in lockstep with one another except for those relative movements studied in Table 5. And those relative movements in real exchange rates are largely nonrandom, being explained by productivity growth differentials.

Table 7.

Internal Prices: Changes in Sector i's Prices Relative to Prices in Manufacturing, 1973-86[a]

Country	Productivity Growth Differentials	Constant	$\bar{R}^2$ (SEE)
U.S.	-1.040 (0.126)	-0.002 (0.002)	.870 (0.007)
Japan	-0.859 (0.068)	-0.002 (0.003)	.940 (0.011)
France	-0.830 (0.186)	-0.002 (0.002)	.654 (0.008)
Germany	-0.828 (0.279)	-0.003 (0.002)	.439 (0.008)
U.K.[b]	-0.901 (0.126)	-0.001 (0.003)	.834 (0.009)

Notes: [a] Standard errors are in parentheses below the coefficients.

[b] The equation for the United Kingdom begins in 1975 because the national accounts data disaggregated by manufacturing sector begin in that year.

This explanation leaves one question unanswered. Is price adjustment more complete internally than externally? Has the randomness of flexible exchange rates so reduced integration of different national markets in any one sector of manufacturing that we find that internal price adjustment between sectors is more complete than external price adjustment in the same sector? In that case prices in sector i in the United States would be more closely linked to those in sector j in the United States than those in sector i in Europe or Japan. That is, the random movement in nominal exchange rates would have made the prices of American "apples" more closely linked to those of American "oranges" than to those of European "apples". The next section addresses this question.

B. Intersectoral vs. International Prices

To compare internal with external price adjustment, the year-to-year variation in the value added deflators is now examined over the 1973-86 period. Yearly variations in internal relative prices can occur in response to either demand or cost shifts within manufacturing. Thus, for example, if demand rises for transport equipment, then prices and profit margins are likely to rise in that sector, so the relative price of transport equipment to manufacturing goods as a whole should rise. Yearly variations in external relative prices within the same industry can also occur in response to demand or costs shifts, in this case changes in the demand for foreign relative to domestic products or changes in relative costs at home and abroad. But variations in external prices are more likely to be driven primarily by nominal exchange rate movements than by demand or cost shifts within any industry. Random movements in nominal exchange rates disrupt normal price relationships between similar products from different countries.

To determine whether internal or external prices are more closely related, we calculated correlations between prices over the period from 1973 to 1986. In the case of internal prices, the correlations are between prices in industry i and manufacturing prices as a whole:

$$(11) \quad r(i, m) = \frac{\Sigma_{t=1}^{T} (P_{it} - \overline{P}_i)(P_{mt} - \overline{P}_m)}{n\, \sigma_i\, \sigma_m}$$

where P_{it} represents the percentage change in the price of industry i's goods, P_{mt} is the percentage change in the price of manufacturing goods as a whole, and $\overline{P}_i$ and $\overline{P}_m$ are the means of these prices changes over the sample period. In the case of external prices, the correlations are between percentage changes in the prices of industry i's goods in the United States and those of industry i in a foreign country:

$$(12) \quad r(i, i*) = \frac{\Sigma_{t=1}^{T} (P_{it} - \overline{P}_i)((P_{it}^{*} - S_t) - (\overline{P}_i^{*} - \overline{S}))}{n\, \sigma_i\, \sigma_{i*}}$$

The prices in industry i in the foreign country are converted into dollars by subtracting the percentage change in S_t, the foreign currency price of the dollar.

Table 8 reports the correlations by industry for the G-5 countries. For each country, internal price correlations are reported first. Then for every country except the United States, external price correlations are reported between prices in that country expressed in dollars and the corresponding sectoral prices in the United States. The last column of the table

Table 8

Internal and External Price Correlations, 1973-86
Annual Value Added Deflators

Sector	U.S. r(i,m)	Japan r(i,m)	Japan r(i,i*)	U.K. r(i,m)	U.K. r(i,i*)
1	0.61*	0.44	0.08	0.66*	-0.20
2	0.48*	-0.33	-0.38	0.76*	-0.19
3	0.62*	0.57*	0.01	0.88*	0.55*
4	0.61*	0.39	-0.05	0.75*	0.22
5	0.81*	0.86*	0.27	0.86*	0.67*
6	0.76*	0.90*	0.16	0.26	0.04
7	0.86*	0.79*	0.34	0.84*	0.57*
8	0.92*	0.83*	-0.12	0.87*	0.42
9	0.42	0.08	0.17	0.78*	-0.14
10	0.83*	0.45	-0.08	0.90*	-0.13
11	0.51*	0.54*	-0.11	0.84*	0.37

Sector	France r(i,m)	France r(i,i*)	Germany r(i,m)	Germany r(i,i*)	F vs. G r(i,i*)
1	0.53*	0.20	0.43	0.06	-0.41
2	0.07	-0.33	0.72*	-0.07	-0.22
3	0.66*	0.38	0.62*	0.12	0.62*
4	0.27	0.18	0.63*	0.19	0.53*
5	0.67*	0.59*	0.51*	0.37	0.28
6	0.29	0.16	0.32	0.12	0.53*
7	0.89*	0.42	0.85*	0.17	0.42
8	0.77*	0.20	0.48*	0.11	0.55*
9	0.32	0.00	0.32	-0.25	0.57*
10	0.38	-0.02	0.76*	-0.23	0.00
11	-0.02	0.01	0.59*	-0.21	-0.09

Correlations:

r(i,m): Correlation between (percentage) changes in prices in sector i and changes in prices in manufacturing as a whole.

r(i,i*): Correlation between changes in U.S. prices and foreign prices in sector i, where both prices are expressed in dollars. In the last column of the table, the correlation is between changes in French prices and German prices, where both prices are expressed in marks.

Note: Any correlations greater than 0.48 are significantly greater than zero at the five percent level. Statistically significant correlations are marked with an asterisk.

reports correlations between French and German prices expressed in marks.

For all five G-5 countries, correlations between internal prices are generally quite high. In the case of the United States, for example, prices in sector 1 (food and beverages) have a correlation of 0.61 with prices in U.S. manufacturing as a whole. Other U.S. correlations range from 0.42 to 0.92. Some of the correlations in the other countries are smaller than these, but of the fifty-five internal price correlations, thirty-nine are significantly greater than zero at the five percent level.

The external correlations are almost invariably smaller than the corresponding internal correlations for the same sector. Consider, for example, the case of Japan. The correlation of sector 1's prices with those in manufacturing as a whole is 0.44, but the correlation of these prices with sector 1's prices in the United States (both expressed in dollars) is much smaller at 0.08. Prices in sector 11 (precision instruments) have a correlation of 0.54 with prices in manufacturing, but a negative correlation with sector 11's prices in the United States. Similar patterns are found for the correlations between U.S. prices and the prices of other G-5 countries. Of the forty-four correlations between U.S. and foreign prices, only four are significantly greater than zero at the five percent level.

The volatility of nominal exchange rates is the key to explaining the lower correlations between external prices than between internal prices. Table 9 reports the variances of manufacturing prices in the G-5 countries when these prices are expressed in local currency and in dollars. The variances are much larger when expressed in dollars. The volatility of nominal exchange rates evidently imparts considerable volatility to foreign manufacturing prices expressed in dollars. So it is not surprising that there is low correlation between these prices and U.S. prices.

Table 9
Variances of Prices in Manufacturing in Local Currency and $'s
1973-86

Currency	U.S.	Japan	France	Germany	U.K.
Local Cur.	0.0015	0.0017	0.0003	0.0003	0.0027
Dollars		0.0164	0.0176	0.0180	0.0207

Sources: Same as Table 4.

Another way to show the influence of exchange rate volatility is to express the real exchange rate in terms of the nominal exchange rate and national cost factors.[8] This can be done using an expression like equation (4) to relate prices to unit labor costs (wages adjusted for productivity). The real exchange rate for manufacturing can then be written as follows:

$$(13) \quad R_m = S + (W_m - H_m) - (W_m^* - H_m^*) + (M_m - M_m^*).$$

The first three terms in (13), representing (percentage changes in) the nominal exchange rate and unit labor costs in the United

[8] This decomposition was suggested by Jerome Stein.

States and the foreign country, are directly observable.[9] Thus it is possible to compare the variance of the real exchange rate to the variances of each of these variables. This is done in Table 10. As is evident from this table, the variances of unit labor costs in the United States and the foreign countries are much smaller than the variances of either real or nominal exchange rates. So it is evident that it is the nominal exchange rate, rather than internal costs, which accounts for much of the variability of the real exchange rate or, equivalently, the variability of external relative prices.

Table 10
Variances of Real Exchange Rates Compared with the Variances of Nominal Exchange Rates and Unit Labor Costs in Manufacturing

Variances of:	U.S.	Japan	France	Germany	U.K.
Real ER		0.0187	0.0173	0.0194	0.0186
Nominal ER		0.0153	0.0182	0.0152	0.0136
ULC	0.0024	0.0059	0.0022	0.0013	0.0045

Sources: For wages, IMF, International Financial Statistics. For other variables, same as Table 4.

The last column of Table 8 reports correlations between French and German prices when both are expressed in marks. Of the eleven correlations reported, five are significantly greater than zero. So there is more evidence of correlation between French and German prices than between U.S. prices and those of

[9] Markups in manufacturing, M_m and M_m^*, are observable only as a residual of prices over unit labor costs.

the other G-5 countries. Yet these inter-European correlations are more often than not lower than the internal correlations for France and Germany. That is, the correlation between French and German "apple" prices are more often lower than between the prices of French "apples" and other French products.

The explanation for this result probably lies in the volatility of the franc-mark exchange rate. Exchange rate arrangements prior to the founding of the EMS in 1979 did not prevent large changes in nominal exchange rates from occurring. In fact, the franc fluctuated quite sharply relative to the mark. In three of those years, the franc depreciated relative to the mark by over eight percent, while in a fourth year it appreciated by six percent. Even after 1979, there were six occasions when devaluations or revaluations of the franc or mark occurred. In 1982 and 1983, the franc depreciated by over nine percent. As Table 6 showed, the exchange rate arrangements <u>did</u> reduce the variability of prices in the partner's currencies. But evidently enough variability remained to lower correlations between French and German prices in a common currency.

The correlations reported in Table 8 are based on annual data for value added deflators. To determine whether similar results apply to higher frequency price series, correlations among monthly producer prices were also studied. The OECD provides producer price indexes defined on a consistent basis for three of the five G-5 countries, Germany, Japan, and the United States. Table 11 reports five sets of correlations, three

Table 11

Internal and External Price Correlations, 1975-87
Monthly Producer Price Indexes

Sector	U.S. r(i,m)	Japan r(i,m)	Japan r(i,i*)	Germany r(i,m)	Germany r(i,i*)
31	0.05	0.47*	0.04	0.47*	0.01
32	0.47*	0.36*	-0.12	0.63*	-0.14
351	0.57*	0.80*	0.06	0.69*	0.17*
371	0.39*	0.52*	-0.02	0.34*	0.00
372	0.35*	0.46*	0.55*	0.89*	0.58*
381	0.44*	0.46*	0.00	0.57*	-0.01
382	0.56*	0.54*	-0.07	0.52*	-0.07
383	0.59*	0.47*	-0.06	0.54*	-0.09
3843	0.33*	0.02	0.02	0.36*	0.07

Sectors:

31: Food, Beverages, Tobacco
32: Textiles, Clothing and Leather
351: Industrial Chemicals
371: Iron and Steel
372: Non-Ferrous Metals
381: Metal Products
382: Machinery (Except Electrical)
383: Electrical Machinery
3843: Transport Vehicles

Correlations:

r(i,m): Correlation between (percentage) changes in prices in sector i and in manufacturing as a whole.

r(i,i*): Correlation between (percentage) changes in U.S. prices in sector i and foreign prices in sector i, where both prices are expressed in dollars.

Note: Correlations greater than 0.13 are significantly greater than zero at the five percent level.

Sources: OECD, *Indicators of Industrial Activity* (WEFA Database); U.S. Department of Commerce, *Business Conditions Digest* (for Sector 382 series for U.S.).

national and two international. For all three countries, there are correlations between sectoral prices and prices in the manufacturing sector as a whole. There are also correlations between Japanese prices and U.S. prices and between German prices and U.S. prices, where all prices are expressed in dollars.

The internal correlations between national prices are almost uniformly high. As in the earlier table, the national correlations relate prices in sector i to prices in manufacturing as a whole. Thus in sector 1, representing food, beverages, and tobacco, there is a correlation of 0.47 between Japanese or German prices in that sector and prices in their respective manufacturing sectors. The sectors are broken down differently than in the value added data, but the results are similar. All but two of the internal correlations are significantly greater than zero at the five percent level.

The international or cross-country correlations are generally much lower. Only three of these correlations are significantly greater than zero. The low correlations should not be surprising given the well-known variability of nominal exchange rates over periods as short as one month. Of the three correlations significantly greater than one, two are in sector 372, non-ferrous metals. There the correlation between Japanese or German prices and U.S. prices is surprisingly high at 0.55 and 0.58, respectively. No obvious explanation can be offered for this result except that prices in that sector appear to have a large seasonal component common to each country. But otherwise, the results based on monthly data in Table 11 confirm those based on annual data reported earlier.

Conclusion

This paper has contrasted the strong ties which bind together prices from different sectors within a single national economy with ties that bind the prices of goods from the same sector internationally. Prices are much more highly correlated internally than externally because flexible exchange rates disrupt normal pricing relationships between goods from different countries.

Except for systematic deviations due to productivity growth, real exchange rates defined for different sectors move in lockstep with each other even though each of the real exchange rates taken alone has a large random component. The real exchange rates are tied together by internal price relationships due to factor mobility within each national economy. Any differences between real exchange rates which develop, moreover, can be explained almost entirely by productivity differentials, at least in the long run.

One surprising finding concerns real exchange rates between France and Germany. The real exchange rate movements across sectors are remarkably similar in magnitude. This is in contrast to real exchange rates between the United States and Japan or the United States and these same European countries. Exchange rate arrangements in Europe may help to explain the movement in aggregate exchange rates between European countries. But in order for sectoral real exchange rates to move together, productivity growth must be similar in France and Germany sector by sector. In fact, productivity growth is very similar across sectors in these two countries.

For all G-5 countries, internal and external price links are investigated through two sets of correlation coefficients based on annual and monthly data, respectively. The evidence developed indicates that internal prices in different sectors are much more highly correlated than prices in the same sector internationally.

REFERENCES

Abuaf, Niso, and Philippe Jorion, 1989, "Purchasing Power Parity in the Long Run," unpublished working paper.

Adler, Michael, and Bruce Lehmann, 1983, "Deviations from Purchasing Power Parity in the Long Run," Journal of Finance, December, pp. 1471-87.

Balassa, Bela, 1964, "The Purchasing Power Parity Doctrine: A Reappraisal," Journal of Political Economy, PP. 584-96.

Frankel, Jeffrey, 1985, "International Capital Mobility and Crowding Out In the U.S. Economy: Imperfect Integration of Financial Markets or of Goods Markets"?, NBER Working Paper No. 1773, December.

Hsieh, David A., 1982, "The Determination of the Real Exchange Rate: the Productivity Approach," Journal of International Economics, pp. 355-62.

Marston, Richard, 1987, "Real Exchange Rates and Productivity Growth in the United States and Japan," in Sven W. Arndt and J. David Richardson, eds., Real-Financial Linkages among Open Economies: An Overview, Cambridge: MIT Press.

Marston, Richard, and Stephen Turnovsky, 1985, "Imported Materials Prices, Wage Policy, and Macro-economic Stabilization," Canadian Journal of Economics, May, pp. 273-84.

Roll, Richard, 1979, "Violations of Purchasing Power Parity and Their Implications for Efficient International Commodity Markets", in M. Sarnat and G. Szego, eds., International Finance and Trade, Vol. 1, Cambridge Massachusetts: Ballinger.

FIGURE 1a
U.S.-JAPANESE REAL EXCHANGE RATES

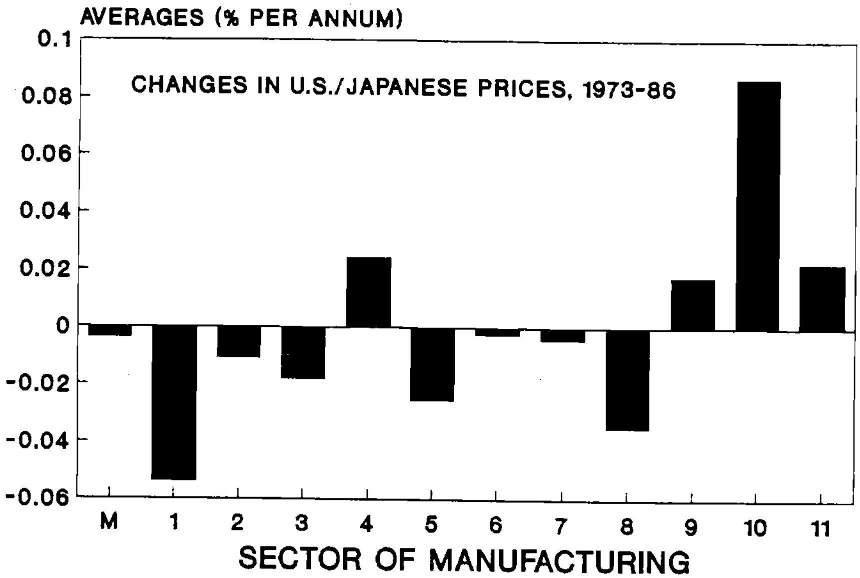

FIGURE 1b
U.S. AND JAPANESE PRODUCTIVITY GROWTH

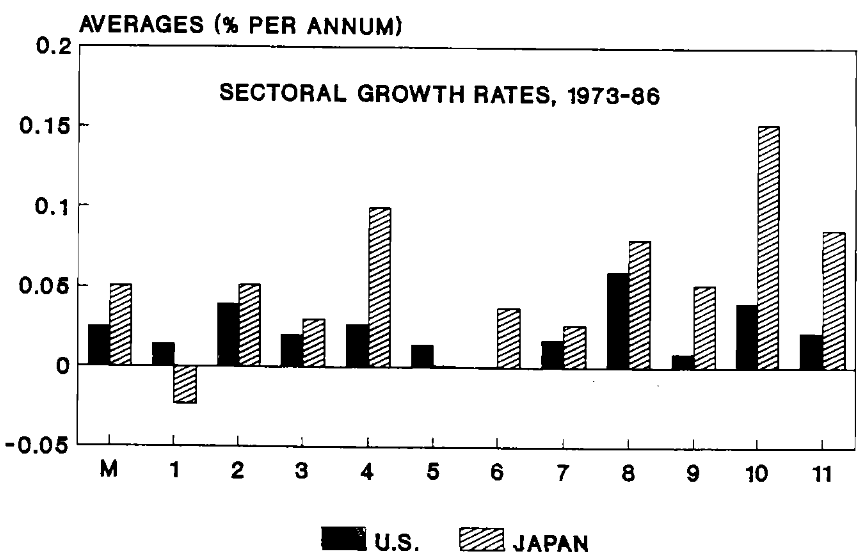

FIGURE 2a
FRENCH-GERMAN REAL EXCHANGE RATES

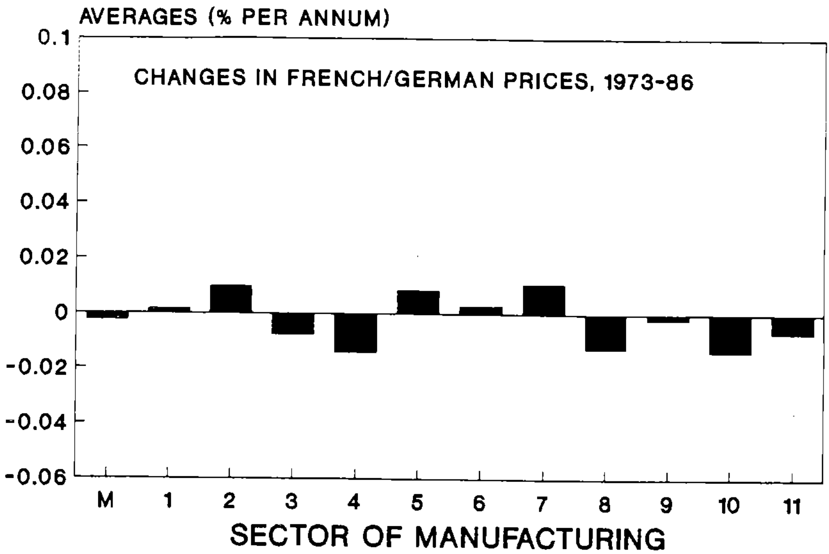

FIGURE 2b
FRENCH AND GERMAN PRODUCTIVITY GR.