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RAW MATERIALS, PROFITS, AND THE PRODUCTIVITY SLOWDOWN

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ABSTRACT

A factor-price frontier framework is used to clarify the analogy of an increase (decrease) in raw material prices with that of autonomous technological regress (progress). Factor-price profiles estimated for the United States, the United Kingdom, Germany, and Japan bring out the major role of raw materials in the profit and product wage squeeze after 1972, with some differences between countries.

The production model, in conjunction with estimates obtained from the factor-price frontier, attributes almost all the slowdown in total productivity to the rise in relative raw material prices. It is also shown that part of the apparent productivity riddle has to do with the common use of double-deflated national accounting measures of value added, which have an inherent measurement bias.

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The years 1973-74 mark a watershed in the economic development of the major industrial economies. This has shown up in a number of different areas, some of them unrelated at first sight. We now know more about the causal relationship between supply shocks, in particular the oil-price explosion, and the post-1973 acceleration of inflation and unemployment, which could not be explained within a traditional demand-oriented macroeconomic framework. Another major post-1973 development is the marked slowdown in the growth rate of labour productivity, which seems to have gone considerably beyond a normal short-run cyclical downturn; this has so far remained an unexplained puzzle. One causal link with the 1973 oil crisis might have been the effect of the profit squeeze in slowing down capital accumulation and its derived effect on output per unit of labour. On further examination, however, it seems that the drop in labour productivity consists of a reduction in the conventionally measured residual factor productivity after accounting for the capital input. Growth accounting studies (such as Denison's [1979] for the business sector) have so far rejected the claim made by Jorgenson [1978] that higher energy prices play the key role in the United States slowdown. The growth accounting method may not be appropriate, but more complex econometric approaches applying a translog production framework to the U.S. manufacturing sector (e.g., Norsworthy and Harper [1979] and Berndt [1980]) have not come out with any more decisive results. The direct energy input is simply too small, percentagewise, to explain the sizeable changes that have taken place in productivity growth. Alternative explanations suggested, such as the slackened pace of innovation (Griliches

[1980] and Nadiri [1980] are not, so far, very promising in explaining the post-1973 break in productivity trends.

In this paper we shall attempt to shift the emphasis to the much wider role of the aggregate material input into manufacturing whose domestic prices, relative to the price of final manufactured goods, increased by 35-40 percent in the early part of the 1970s, and have since, with minor fluctuations, remained high. This can be contrasted with the 1950s and 1960s, in which there was a systematic downward trend in these prices. (See Enoch and Panić [1981], Lipsey and Kravis [1981], Bosworth and Lawrence [1981].)

It is only natural that in a world of relatively stable raw material prices, economic analysis should have been conducted in terms of a net product derived from the two major primary factors of production, labour and capital. Once relative raw material prices change, this is no longer a valid procedure, and it may give misleading empirical results. On the other hand, bringing the third factor into the analysis complicates matters. Macro- or trade-theory models with intermediate goods or econometric three- or four-factor production function studies tend to get very complex, and it is often hard to see the wood for the trees.

The first object of this paper is to provide a relatively simple and transparent framework within which the main short-run and long-run real effects of raw material price increases, and in particular their effect on the manufacturing sector, can be analysed. This framework is based on the factor-price frontier, which provides a concise summary of the interactions of the technology, factor use, and real factor price effects. In particular, it brings out most clearly the analogy of an increase (decrease) in raw material prices with that of autonomous technological regress (progress).

In Section I, we consider a small open economy (or sector) producing one final good under the assumption of weak separability of the imported raw material. An alternative capital/raw material complementarity case is also analysed. Quite a lot of what is known about more complex economies comes out of this simple model.

The second part of the paper analyses and compares some of the main long-run changes in the manufacturing sector of four major industrial economies--the United States, the United Kingdom, Germany, and Japan, in terms of a two-level production model and its dual. The respective factor-price profiles bring out the major role of raw material in the profit and product-wage squeeze after 1972, with some interesting differences between countries (Section II). It also throws some light on the cyclical versus long-run behaviour of profits for the United States (cf. Feldstein and Summers [1977]). Section III addresses itself to the empirical question raised at the beginning. The production model, in conjunction with some estimates obtained from the factor-price frontier, can be used to attribute much of the slowdown in total productivity to the rise in relative raw material prices. With the possible exception of the United Kingdom, there is no large residual left unexplained. It is also shown that part of the apparent productivity riddle has to do with the common use of double-deflated national accounting measures of value added, which have an inherent measurement bias.

I. THE FACTOR PRICE FRONTIER AND THE REAL EFFECTS OF MATERIAL INPUT PRICES

Let $Q = Q(L,K,N)$ be a well-behaved production function for gross output of a final good using labour, L, capital, K, and a material, or an intermediate input, N. The price of the output is P and that of the material is P_n.

For the time being, assume that the relative price $\Pi_n = P_n/P$ is given (as is the case if both N and Q are tradeable goods in a small open economy). Let Y be the real income derived, $Y = Q - \Pi_n N$, and assume optimal use of N such that $\partial Q/\partial N = \Pi_n$. Substituting in Q( ), one obtains a value-added function,

$$Y = Y(L,K;\Pi_n) , \tag{1}$$

with the following properties:[1] (a) $\partial Y/\partial L = \partial Q/\partial L$, $\partial Y/\partial K = \partial Q/\partial K$, $\partial Y/\partial \Pi_n = -N$. (b) If the Q production function is linearly homogeneous in the three factors, L, K, and N, the Y function will be linearly homogeneous in the primary factors L, K so that the Euler equation holds for Y(K,L):

$$\frac{\partial Y}{\partial L} L + \frac{\partial Y}{\partial K} K = Y . \tag{2}$$

Now consider changes in Π_n. Using lower case letters to denote log of upper case variables, the rate of change of Π_n is $\dot{\pi}_n$. It immediately follows that *the partial elasticity of value added with respect to a real change in the price* Π_n *is the ratio of the relative shares of the material and value added in gross output.*

Proof: $\partial Y/\partial \Pi_n = -N$, thus,

$$\frac{\Pi_n}{Y}\frac{\partial Y}{\partial \Pi} = -\frac{\Pi_n N}{Y} = -\frac{P_n N}{PQ - P_n N} = -\frac{\beta}{1-\beta} , \tag{3}$$

where $\beta = P_n N/PQ$ (share). Q.E.D.

A simple corollary of this proposition is that a policy aiming at keeping *relative* domestic factor shares constant in the face of a real change in raw material prices requires both factor rentals to decrease at the rate

$\dot{\pi}_n \beta/(1 - \beta)$, for given factor inputs.

This may be used to measure net terms-of-trade effects on factor rewards (see, e.g., Sachs [1979]). It does not require that workers receive their marginal product, only that the raw material be used optimally. Note too that the fixed-proportion case $(N = \mu Q)$ can be looked on as a limiting case for which the proposition holds directly: one has $Y = Q(1 - \mu \Pi_n)$ and therefore $\partial Y/\partial \Pi_n = -\mu Q = -N$.

This analysis easily generalizes to the case in which N is a vector of several inputs N_i with relative prices $\Pi_{ni} = P_{ni}/P$ $(i = 1, 2, \ldots, s)$. We now have $Y = Q - \Sigma_i \Pi_{ni} N_i = Y(L, K; \Pi_{ni}, \ldots, \Pi_{ns})$, $\partial Y/\partial \Pi_{ni} = -N_i$, and $(\Pi_{ni}/Y)(\partial Y/\partial \Pi_{ni}) = -\beta_i/(1 - \beta_i)$, where $\beta_i = \Pi_{ni} N_i/Q$, $\beta = \Sigma_i \beta_i$, and the rate of decline of real income (and the factor shares), holding L and K constant, will be $b = (1 - \beta)^{-1} \Sigma_i \beta_i \dot{\pi}_{ni}$.

Note that the "technical regress" term, $-b$, is measured as a weighted Divisia index of material input prices. When L and K change , we have $\dot{y} = (1 - \beta)^{-1}(\alpha \dot{\ell} + \gamma \dot{k}) - b$, where α and γ are the output elasticities (shares) of labour and capital in Q . It follows that the rate of change of V , real net output, is precisely

$$\text{(4)} \qquad \dot{v} = \dot{y} + b = (1 - \beta)^{-1}(\alpha \dot{\ell} + \gamma \dot{k}) = (1 - \beta)^{-1}(\dot{q} - \beta \dot{n})$$

Below we shall rewrite (4) with an independent time shift (technical progress) term added on.

If the real product wage does not change, upon impact of a Π_n shift, what will be the effect on the rate of profit? No functional specification is required to give an approximate answer. The change in the log of the real rate of profit, $\dot{r}$, satisfies the following equation,[2]

(5) $$\dot{r} = -(\alpha\dot{w}_p + \beta\dot{\pi}_n)/\gamma \ ,$$

where w_p is the log of the real product wage, $W_p = W/P$, and α , β , and γ are the factor shares (as above) which need not be constant. The partial elasticity of the rate of profit with respect to the increase in raw material prices is thus $-\beta/\alpha$. If, say, $\beta = 0.30$, $\alpha = 0.50$, this implies that with a constant real product wage, a 40 percent increase in Π_n leads to a 60 percent drop in the rate of profit in manufacturing, not unlike some actual developments in the 1970s (e.g., in the United Kingdom).

There is a polar case in which the real rate of return is assumed to remain constant in the long run while the real wage becomes flexible downward. Suppose that investment decisions are governed by a given long-run real rate of interest, R_0 (based on time preference or alternative international investment opportunities). In that case, there will be a process of capital decumulation which will come to an end only once the marginal product of capital returns to the initial pre-shock level, R_0 . The required drop in the real wage is greater than in the short run and is given approximately by $\dot{\pi}_n\beta/\alpha$ [see equation (5) for $\dot{r} = 0$; obviously, $\beta/\alpha > \beta/(1 - \beta)$] .

The next question relates to an intermediate short-run situation in which the capital stock is fixed and real wages are flexible. If employment is to remain constant in the face of a given increase in Π_n , by how much must the real product wage and the real rate of return fall? At this point we make a simple but important assumption--that the production function is *weakly separable* in the material input, $Q = Q[G(L, K), N]$. This implies that the marginal rate of substitution between labour and capital depends only on L/K and is independent of N [Leontief, 1947].

Consider a short-run situation in which $K = \bar{K}$ and now require also that $L = \bar{L}$ (constant or full employment). It follows that $(\partial Y/\partial L)/(\partial Y/\partial K)$ stays constant and so do relative factor elasticities. Under profit maximization, factor rentals equal their marginal products, and thus the incomes policy rule stated before holds. We can now state the following proposition: *Under weak separability of material inputs and an increase in their real price (at rate* $\dot{\pi}_n$*), the level of employment will stay constant in the short run if and only if the marginal products (rentals) of labour and capital fall by the same proportion,* $\dot{\pi}_n[\beta/(1 - \beta)]$ *. Thus, a raw material price increase acts on real factor incomes exactly like Hicks-neutral technical regress.*

The analysis is best handled by appealing to the concept of the factor-price frontier (FPF), which summarizes the information about the technology in terms of the maximal combinations of the three marginal factor products, $F(W_p, R, \Pi_n) = 0$. The curve F_0 drawn in $W_p - R$ space (see Figure I) for a given relative raw material price Π_{n_0} is downward sloping and convex to the origin. The slope of the tangent at any point measures the capital/labour ratio that corresponds to the pair of factor prices, and its intercept on the W_F axis (OT) measures Y/L . Likewise, the intercept on the R-axis (OS) measures Y/K . Weak separability of the production function implies weak separability of the dual FPF, i.e., F_0 takes the form $F[f(W_p, R), \Pi_n] = 0$. A material input price increase, like Hicks-neutral technical regress, is thus represented by a homothetic inward shift of F_0 to F_1 . At the point C on the new FPF, on the ray OA , the capital/labour ratio is the same as at A . C is a full-employment point, in the *short run* (when $K = \bar{K}$, $L = \bar{L}$) . Marginal factor products at C are reduced by the same ratio from their original level at A . Total real income per unit of labour (Y/L) falls by the same proportion from OT to OM (and Y/K from OS to ON). The case of real wage rigidity at

W_{p_0} , which may occur in the *very short run*, is represented by the point B where R must of necessity fall by more than at C and the capital/labour ratio is higher than at C . At the given capital stock, $\bar{K}$, unemployment will emerge. For the putty-clay case in which the capital/labour ratio cannot immediately adjust to the new factor prices, the various solutions are given along the line FCG' i.e., in the rigid real wage, rigid capital/labour ratio case, the economy will be at F and not at B , the rate of profit falling more than at B.

The polar case of an externally imposed long-run real rate of interest (equal to R_0 , say) is represented by the point D , at which the real wage and the capital/labour ratio are below their levels at C. In contrast to C, the point D may represent a *long run* equilibrium steady-state level after capital has adjusted to a given R_0 . With full employment of labour at D, capital and output (gross and net) are both lower than at the initial point A.

While the case of weak separability of intermediate inputs may be relevant for most industrial raw materials, it is most probably not applicable to the case of energy inputs, E, for which separability may take the alternative form Q[L, G(K, E)] (see Berndt and Wood [1979]). Here energy combines with capital to form a composite from which labour (and other materials, here left out) are separable. By analogy, the resulting factor price frontier in the W_p - R space will now contract along the R axis at the rate $\dot{\pi}_e\beta_e/\gamma$ (where β_e is the share of energy and π_e its log price). This rate will be independent of the real wage. For simplicity consider an even more special case in which the energy input is fully complementary to capital. In this case $Q = Q[L, \min(K, E/\eta)]$, and $R = Q/K - W_pL/K - \Pi_e\eta$. Suppose F_0 is the initial FPF, for a given Π_e. An increase of $\Delta\Pi_e$ in the energy price then implies that F will shift to the left by $\eta(\Delta\Pi_e)$, i.e., at all levels of the real wage the rate of return falls by the same amount. The resulting FPF denoted by

F' will cut F_1 at the point B and will lie right of F_1 for all $W_p < W_{p_0}$.[3]

Consider again the implications of a material price increase. Here, unlike in the previous model, full employment can in the short run be maintained at the initial real wage W_{p_0}, since the optimum capital-labour ratio stays the same while the net rate of return to capital[4] falls by the amount $\Delta R = -\eta \Delta \Pi_e$. In the long run, if the real rate of interest is R_0, the capital stock and the real wage must adjust downwards to equilibrium at the point E. The new steady-state real wage at E is clearly above, and the capital-labour ratio below, the respective long-run equilibrium levels under the previous technology (compare the points E and D and the respective tangents at these points), but otherwise the long-run implications remain the same. The short-run effect on labour demand is, of course, different.[5]

To see the short-run and long-run implications of a raw materials price shock in this one-sector model, one may consider some simple dynamics in terms of two key variables, the real wage and the capital stock. The change in the real wage would react to unemployment and the change in the capital stock (investment) to the difference between r and r_0. This analysis is omitted here. The upshot is that a raw material price increase in the single-sector economy must, in the long run, entail a fall in the real wage and in the equilibrium capital stock. This is so under both alternative technological assumptions made. Whether or not there is unemployment in the short run depends on the technology; whether there is unemployment along the dynamic path to equilibrium in either model depends on the extent of real wage rigidity.

This analysis can clearly be modified and extended in several directions. Most of these extensions lie outside the scope of the present paper, which attempts to apply the FPF framework to a single large sector--manufacturing.

Some of these modifications will nonetheless be indicated briefly so as to put the analysis that follows in proper perspective.

The first natural extension of the model would be to consider additional sectors within a single economy. One candidate is an extractive sector whose relative output price and profitability increases with Π_n. It thus gradually takes over from the final goods sector as an employment-absorbing and capital-attracting sector. It can be shown that if the country is not self-sufficient in raw materials and the sector is relatively capital-intensive, the short-run effect of a rise in raw material prices will still be to increase overall unemployment. An alternative source of employment could be a domestic nontradeable goods industry (e.g., private or government services) which does not use raw materials as an input.[6]

Another modification to the model would do away with the small-economy assumption with respect to final goods prices. If the final good is an imperfect substitute for the world good (priced P^*), the relative raw materials price now depends on the final goods terms of trade, P^*e/P. We have $\Pi_n/P = (P^*e/P)(P_n^*/P^*)$, where $\Pi_n^* = P_n^*/P^*$ is the world relative price of raw materials. Even if one only wants to apply this factor-price analysis to a single large sector, one should keep in mind that the relative price Π_n may now depend also on the real exchange rate , and demand management in the economy as a whole. For example, an external raw materials price shock (increase in Π_n^*) may be followed by a real appreciation (a decline in P^*e/P) and the sector's FPF may partly shift back. Next, if the external final good is also imperfectly substitutable in domestic consumption, the concept of the real consumption wage (and of real wage rigidity) must be suitably adjusted.[7] Finally, one should bear in mind that when it comes to a world equilibrium, the real rate of interest (R) becomes an endogenous variable. There are good reasons, both theoretical and empirical, to suggest that one of the by-products of a supply shock affecting all industrial countries simultaneously is a reduction in R, at least temporarily. This, too, will be discussed elsewhere. Needless to say, the FPF analysis of the single small economy gives only part of the story, but for our present purpose it may be the most important part.

II. EMPIRICAL FACTOR-PRICE PROFILES

Empirical Background

In this section we turn to an empirical illustration of the factor-price profiles for the manufacturing sector of four major industrial countries: the United States, the United Kingdom, Germany and Japan.

Table I summarizes the change in the key cost and quantity variables during 1955-1980 (Only the U.S. and U.K. data are almost covered for 1979-1980). The period 1955-1972 can be looked upon as representing a "normal" growth phase, 1972-1975 covers the response to the first oil and raw materials price explosion, and 1975-1978 is a period of partial recovery before the next price hike (1979-1980) set in. Panel 1 of Table I shows the sharp deceleration in output per man-hour after 1972 and the partial recovery after 1975. In Germany the fluctuation was much milder.[8] The existing observations for 1979-1980 show the renewed slowdown after the next price shock.

Panel 6 of the table shows the rate of profit in selected years. There is some evidence of a long-run fall in the rate of profit during the 1960s which may be connected with capital deepening and a secular increase in unit wage costs, and which can be seen by comparing the growth rate figures of the product wage with labour productivity. While this is an interesting development in itself, we shall not specifically discuss the period here (see, for example, Glyn and Sutcliffe [1972] and Sargent [1979]). Between 1972 and 1975 there was a very sharp drop in the profit rate (again Germany is the exception), which shows only partial recovery in the subsequent period. Preliminary rough estimates for the first two countries suggest another profit squeeze by 1980. Comparison of product-wage behaviour in 1972-1978 with its 1955-1972 trend provides some interesting intercountry differences.

The table (panel 4) also gives a measure of the change in the real cost of intermediate goods used by the manufacturing sectors in the four countries. These data appear in more detailed form in Figure II. For all four countries, an attempt was made to use an index which is as close as possible to the wholesale price index for the aggregate material input into the manufacturing sector, and deflate it by the manufacturers' wholesale price. Conceptually this would include fuels, unprocessed foods from agriculture, and all other material or intermediate inputs imported from the rest of the economy or from abroad. It is important to stress that in most cases fuels constitute only a relatively small share of this index.

Most of the action in the exceptional input price behaviour over this period is not directly accounted for by oil prices, although it may in part be indirect (raising extraction and production costs). To show this, we have also included an international index of the non-fuel primary exports relative to manufacturing export prices. This was recently constructed by Kravis and Lipsey [1981][9] and shows a broadly similar pattern. Obviously the individual country patterns need not be identical, because of the movements in relative exchange rates and the different domestic government pricing policies. A particular case in point is Germany, which had a sharp real appreciation in the 1970s, and which also kept internal energy and agricultural prices low.

Two basic facts stand out from Figure I. One is the sustained and unambiguous real price shock of the early 1970s (of the order of 40% for the U.K. and Japan, 30% for the U.S., and only 10% for Germany). With some fluctuations and one or two additional mini-shocks, the high level was, by and large, maintained to the end of the decade. The other fact worth point out is that for three of the countries (excluding Japan), this unprecedented shock was preceded by 15 years of steady decline (of the order of 1% a year) in the relative cost of the material input, closely associated with the relative decline of these prices (and of oil) in the world market.

Analysis of Factor Price Profiles

Specification of the factor price frontier depends on the choice of an underlying production function; its estimation could be done jointly with estimation of the quantity model. We delay illustration of such a jointly estimated model to the next section and confine ourselves here to the analysis of factor price profiles based on single equation estimation. The choice of the functional form is consistent with a simple production model, and, as we shall see, the empirical estimates will not be substantially altered when we come to the alternative estimation technique.

A number of authors have used a general four-factor (K, L, E, M) translog production framework for estimation purposes. While this may be the best approach for some purposes (e.g., specific concern for the energy input), the results of such estimates also suggest that for a broad view of developments, a simplified model may do no worse, and for our present purposes may be better. We shall lump all intermediate goods, including energy, into one input and choose the simplest production function which still seems a sufficiently realistic approximation.[10]

The size of the direct energy share in total manufacturing output is of the order of 2-3%, compared to an order of magnitude of 30-65% for all other material inputs, depending on the degree of aggregation or consolidation of the manufacturing sector from its constituent parts.[11] If the non-energy input can be assumed to be separable while energy may not be, the extent of overall error coming from imposing separability on the aggregate input cannot be large.

Another simplification involves the implicit assumption that the prices of the aggregate input of intermediate goods from the manufacturing sector into itself move at the same rate as the wholesale price of the manufacturing output. This enables one to net out this input and consider manufacturing production as using only labour, capital and materials (and intermediate goods) purchased from outside the sector. This is certainly not an ideal choice but is one that has to be made in the absence of a detailed and fully consistent time series account of quantities and prices in the input-output system of the countries investigated here.[12]

Finally we come to the choice of functional specification. The simplest would be to use a linearized level form of equation (5) with an independent term for technical progress. If the underlying production function were Cobb-Douglas in all three factors, this would be precisely correct. While a reasonable assumption for the pair of labour and capital inputs in net product $V(K, L)$, it makes no a priori empirical sense for the substitution between N and V. We shall choose a two-level production function with an unrestricted constant elasticity of substitution (σ) between the material input N and the net product index V where the latter in turn is assumed to be a Cobb-Douglas function for K and L.[13] The second order approximation to the FPF of this function yields a functional form which is like that of the general Cobb-Douglas with only one second order (π_n^2) term which, however, can be ignored for empirical reasons.[14] We end up estimating the following profit function (in log level form):

$$(6) \qquad r = a' - (\alpha/\gamma)(w_p - \lambda t) - (\beta/\gamma)\pi_n + \delta j \ .$$

The first coefficient (α/γ), measuring the relative labour/capital shares, is expected to be constant by assumption, while the second (β/γ) should measure the relative materials-capital share evaluated at a base point (for which $\ell n\, \Pi_n = 1$).

The additional intensity variable $j = \ell n\, J$ is a proxy for cyclical variations, here measured by deviation of the weekly hours worked from the long-run trend. Its possible role in the production model will not be discussed here. It is of importance in explaining the fluctuations of profits primarily in the case of the U.S.

Table II gives a selection of the relevant regressions for equation (6). The estimates for the labour-augmenting productivity factor, λ, the share of capital in value added, $\phi = \gamma/(1 - \beta)$, and the share of intermediate goods in total costs, β (bottom panel), all have the right orders of magnitude. Figures III and IV give a graphic representation of the factor price profiles for the various countries. For the United States and Japan, the figure corresponds to the first regression shown for each of them in Table II.

Each of the charts is drawn in terms of the actual rate of profit (R) on the horizontal axis and the detrended product wage $(W_p' = W_p e^{-\lambda t})$ on the vertical axis, using the λ coefficient estimated from the regression. The solid curves represent estimated factor-price frontiers drawn for given levels of Π_n (and normal man-hours, i.e., $J = 1$), one representing an average pre-1973 level, the other an average post-1973 level of raw materials prices (the implicit rate of change, $\Delta\pi_n$, is noted in each graph). For the two countries represented in Figure III (the United Kingdom and Germany), the regression estimates (dotted lines) are shown along with the actual observations, and the horizontal distance between corresponding annual points measures the regression errors. For the United States (Figure IV below), the underlying "decycled" observations are also plotted; these correct the profit rate by the intensity factor $(19 \times j)$ from the regression [column (1) of Table II], and thus uncover an underlying long-run pattern which is not markedly different from that of the United Kingdom or Japan.

For all countries, a schematic description would suggest that until 1972 there was an upward movement in W_p' (downward in R) more or less along a given FPF, a clear shift to a new FPF after 1972 and movement down the new curve after 1973-1974. Clearly there are some differences between countries in the timing and extent of the downward adjustment of the real wage after 1974 (and the upward readjustment of the rate of profit).[15] The United Kingdom initially showed greater real wage rigidity than Japan and the United States (with a correspondingly tighter profit squeeze) and then over-reacted in 1977 (preliminary figures for 1978-1980 suggest that the product wage rose back and the profit rate continued to fall; the picture also shows an out-of-sample forecast of R to 80). Japan shows the most marked reduction in real product wage (relative to the 11 percent trend, which may be somewhat excessive). By 1977-1978, it had in fact undergone a drop of about 15 percent in both R and W_p' $[= W_p \exp(-0.11t)]$, more or less *pari passu* with the rise in the cost of raw materials, $\Delta\Pi_n\beta/(1 - \beta)$, as suggested by the analysis of Section I.

In some ways the case of the United States (Figure IV) is the most interesting. It is not surprising that the debate about whether the rate of profit in the United States has been falling over time (see Feldstein and Summers

[1977]) has so far been inconclusive. In the United States, more than in any of the other countries, the fluctuations in the rate of profit turn out to be dominated by the cycle. However, once the J variable is introduced, the same long-run structural features emerge. Note that the 1974-1975 dip in profits (to about 0.08 percent) was mostly, though not entirely, cyclical. A comparison of 1978 with 1972 gives an approximate view of the total net effect of the raw materials price hike on the profit-maximizing level (R^*), a drop in the rate of profit by about 10 percent (1.5 percentage points out of 13.4; see Table I). The trend fall in R^* from 1955 to 1971 is estimated at about 15 percent (2.5 percentage points out of 16 percent; compare the asterisked observations for the two years). This took place *pari passu* with a 20 percent rise in W_p which was partly moderated by a 12 percent drop in Π_n (the asterisked 1971 observation lies much closer to the first FPF than the 1955 point).[16] The figure also includes an out-of-sample forecast of R to 1980 suggesting a further fall in the rate of profit.[17]

In view of the very strong role of the cyclical variable in the United States, various alternatives were tried out to see how robust the results are. Using the measure of capacity utilization published by the FRS (j'), one gets essentially the same results except that the coefficients for w_p and π_n are less significant.[18]

The case of Germany also merits a brief separate discussion. In spite of a much smaller rate of change in real raw materials cost, the resulting elasticity with respect to Π_n came out highly significant, and the estimated coefficients of the production function are very reasonable. However, the response to the 1973-1974 events was much milder than in the other three countries. The Π_n of the two curves in Figure III are only 11 percent apart.[19] The main secular change observed on the factor price profile is the upward trend in W_p and the accompanying downward movement of r, in which the raw materials price had only a minor role to play. The 1973-1974 shift seems to have moved the sector back to the FPF on which it had been in the 1960s. The accompanying changes in factor rewards were relatively minor, and as we shall see again later, the same is true for productivity change. This relatively minor effect is directly related to the smallness of the shift in real raw materials prices (see Figure II), which in turn is related to the appreciation of the German exchange rate.

The German case brings out the fact that our discussion of the FPF for the manufacturing sector is of necessity limited here by the fact that we are ignoring the links of the major factor prices with the rest of the economy. Short of embedding the relationship analysed here within a complete general equilibrium model for the main markets (commodities, labour, and foreign exchange), one could at least try to assess the possible simultaneity bias in the estimates. For the United States, Table II lists an alternative regression which was estimated by two-stage least squares (using lagged values of the variables and ℓ as instruments for w_p and π_n). The model does not seem to be much affected by this modification. A similar attempt for the United Kingdom and Germany leaves the coefficient for π_n unaffected, but suggests some simultaneity problem in j and w_p. Additional estimates are discussed below.

III. RAW MATERIAL PRICES AND PRODUCTIVITY CHANGE

If one knew the exact shape and time shift of the factor price frontier, it should, in principle, convey all the information that one would want to know about factor use and total factor productivity. In the present instance, the simple functional form chosen has its advantages as a descriptive device, but is too rough to convey all the required information, e.g., about the degree of substitutability of materials and the domestic product. The latter is of crucial importance if one wants to assess the possible role of raw materials in accounting for the apparent slowdown in total productivity. Since the data used here are not derived from a consistent source and we do not necessarily assume continuous profit maximisation, one would in any case want to double-check by also considering the quantity side.

The CES specifications for the function Q(V, N) lends itself to a straightforward expression for total productivity change. A basic property of CES, in rate-of-change form, is the simple relationship between unit factor use and its relative price. For the material input, we thus have

$$(7) \qquad \dot{n} - \dot{q} = -\sigma\dot{\pi}_n ,$$

where σ is the elasticity of substitution between N and V . Substituting for $\dot{n}$ on the right-hand side of equation (4) and adding a labour augmenting technical progress shift factor (λ) as well, one gets

$$(8) \qquad (\dot{q} - \dot{\ell}) - \phi(\dot{k} - \dot{\ell}) = \lambda(1 - \phi) - (1 - \beta)^{-1}\beta\sigma\overset{\circ}{\pi}_n ,$$

where $\phi = (1 - \beta)^{-1}\gamma$ is the share of capital in value added.

The left-hand side of equation (8) is the conventional period-by-period standard measure of total factor productivity (the "residual") in gross output rather than value added terms. This has the advantage that q is, in principle, based on market observables while real value added $(\dot{v})$ is not (see Section IV for the bias in double-deflation measures). The right-hand side breaks this residual down into the slowdown effect of an increase in material prices[20] and the constant time shift factor. In the empirical work reported below, we shall at times also add the measure of cyclical deviations (J) from trend, here measured by the deviation of weekly hours worked from their trend.

In principle, one could use the observed shares ϕ, calculate the residual for each period as is usually done, and then try to regress the residual on $\dot{\pi}_n$ (and other variables such as the change in J). It is surprising that this has apparently never been attempted in this form. Alternatively, if one is not sure whether actual shares are the "true" ones, one could transfer the $(\dot{k} - \dot{\ell})$ term to the right-hand side of (8) and fit it as a mixed production function, on the assumption that ϕ is constant, i.e., V(K, L) is Cobb-Douglas. Rough estimates of such a relationship may be obtained directly from a combination of cross-section and time series on the assumption that ϕ, β and σ are approximately the same across countries. The following regression was run for ten OECD countries (Canada, the United States, Japan, Belgium, France, Germany, Italy, Netherlands, Sweden, and the United Kingdom) for the period 1956-1978:

$$(9) \qquad \Delta\log(Q/L) = c_t + c_i + \underset{0.054}{0.266}\Delta\log(K/L) - \underset{0.054}{0.179}\Delta\log\Pi_{n_{-i}} \quad (R^2 = 0.574),$$

where c_t and c_i are, respectively, time and country dummies. The average implied relative share of capital looks reasonable, and the coefficient of π_n is negative and highly significant.

If we take β to be approximately equal to 0.35 (see Table II for most regressions) the regression (9) would imply a value of $\sigma = 0.33$. Existing estimates obtained from more complex models for individual countries point to a range of values for which 0.33 seems to be a lower bound. Estimates for two countries can be based on translog functions. These are: 0.45 for the

U.S. and a range of 0.5-0.7 for Japan. In the two other countries, recent estimates have been obtained based on a two-level CES function. These are a range of 0.33-0.8 for the U.K. and 0.32 for Germany.[21] In all cases the coefficients are highly significant.

Since the above individual country estimates have been obtained under varying specifications of the underlying model, we shall also report the result of attempting to fit the present simplified model directly. Table 3 reports two sets of regression estimates. For each country, a two-equation model was run simultaneously, consisting of the FPF (6) in level form and the output equation (8) in first difference form,[22] with the raw material price change lagged one year. These are maximum likelihood (FIML) estimates utilizing the cross-equation restrictions implied by the model for the shares ϕ, β and in most cases also for λ.[23] We have also run (8) independently as a single equation, restricting the values of ϕ and β to be equal to their point estimates previously obtained from the FPF in Table II. The method of estimation for each regression is indicated in the last row of the table.

With the exception of the U.S. or cases in which the intensity variable was included in the productivity equation, the various models yield significant and reasonable values for the elasticity of substitution (σ). It is surprising that a single equation regression for the pre-shock period (1959-1972) in the U.S., when π_n was actually falling, gives a highly significant estimate (0.57), but it fails to show in the joint regressions for the longer period 1957-1980.[24] It is less surprising that inclusion of j renders σ insignificant because, at least in part, the drop in j after a rise in π_n is endogenous. A more detailed specification of the demand side is required before the separate role of commodity prices in shifting demand and supply curves can be correctly assessed. The Durbin-Watson statistics for some of the regressions are low. This is particularly marked for the U.K. productivity regressions. The residuals in those clearly point to a growth slowdown that is not captured by the existing estimate of the effect of π_n (and of j in column (6) of Table III).

The overall adequacy of the raw material price hypothesis can alternatively be gauged by comparing the unexplained slowdown in the total productivity residual between the 1960s and the 1970s with the increase in the average change of material prices, and asking what is be the implied value of σ that would "explain away" the residual. This calculation is given in Table IV (row 10). The resulting estimates which are all below unity can be compared with the assortment of estimates of the elasticity of substitution found in Table III and in the other studies quoted above. Such comparison suggests that Japan and Germany are 'right' or even over-explained. The U.S. seems to have some unexplained residual (unless we accept the high estimate op. cit.) and the U.K. seems to show a more sizeable discrepancy depending on whether we accept the low estimates of 0.35-0.45 of Table III or the highest number quoted from the other study (0.8). In any case, even a skeptic should admit that the rankings of countries by the standard total productivity slowdown and the rate of change of material prices (comparing orderings within rows 7 and 8 of Table III) are perfectly correlated!

IV. THE MEASUREMENT BIAS OF DOUBLE DEFLATION

It is natural to ask why one should use gross output for the measurement of net productivity changes when a net value added concept could be used which one would expect to be free of raw material price effects. One could, in principle, make correct total productivity measurements from value added figures, provided they are obtained from underlying gross output and intermediate input measures based on a Divisia index procedure. Researchers, however, often rely on the usual national accounting figures obtained by double deflation (see Denison [1979] and Norsworthy *et al.* [1979]). While this should cause no problems so long as relative intermediate goods prices did not change much, it brings about considerable measurement bias when this is no longer so. To see what is involved, consider our present production-function specification.[25]

For the production function, we have $\dot{q} = (1 - \beta)\dot{v} + \beta\dot{n}$. From (7) we get $\dot{n} = \dot{q} - \sigma\dot{\pi}_n$; therefore,

$$\dot{v} = \dot{q} + \sigma\dot{\pi}_n\beta/(1 - \beta) \ . \tag{10}$$

Denote double-deflated value added by V_d . We have $V_d = Q - N$ (assuming $\Pi_n = 1$ at $t = 0$). Therefore,

$$\dot{v}_d = \frac{Q\dot{q} - N\dot{n}}{Q - N} = \dot{q} + \frac{N}{Q - N}\sigma\dot{\pi}_n = \dot{q} + \sigma\dot{\pi}_n\beta/(\Pi_n - \beta) \ . \tag{11}$$

Comparing (10) and (11), we get the size of the bias in the measured growth rate of real value added,[26]

$$\dot{v}_d - \dot{v} = - \dot{\pi}_n\beta\sigma/(1 - \beta)(\Pi_n - 1)/(\Pi_n - \beta) = - \frac{\beta\sigma}{1 - \beta}\frac{\dot{\pi}_n(\Pi_n - 1)}{\Pi_n - \beta} , \tag{12}$$

Inspection of equation (12) leads to several conclusions. First, there will be no bias only if we have fixed proportions ($\sigma = 0$), or if there is no change in raw material prices ($\dot{\pi}_n = 0$). Next, for all monotonic changes in Π_n (both up and down), the bias is always negative ($\dot{v}_d < \dot{v}$) and grows as we move away from $t = 0$ ($\Pi_n = 1$). This follows from the fact that $\dot{\pi}_n(\Pi_n - 1) > 0$ whenever Π_n consistently rises or falls over time, and from the fact that $(\Pi_n - 1)/(\Pi_n - \beta)$ is an increasing function of Π_n for $\Pi_n > 1$ (and decreasing for $\Pi_n < 1$).

Consider the approximate order of magnitude of the bias in the present case if value added is measured in constant 1972 prices.[27] The right-hand side of equation (12) consists of the product of the raw materials prices term in the productivity equation and the factor $(\Pi_n - 1)/(\Pi_n - \beta)$. For $\beta = 0.35$ and $\Pi_n = 1.40$, for example, this last factor is 0.38. Suppose we take all of the observed residuals (row 7) in Table 4 as an approximate measure of $\dot{\pi}_n\beta\sigma/(1 - \beta)$ for each country. This would imply that the approximate downward bias in the measurement of the annual product growth rate could reach as much as (in percent) 0.6, 1.1, 0.2, and 1.3 for the United States, the United Kingdom, Germany, and Japan, respectively. Even if the bias were only half as great, these would still be considerable errors in productivity growth measurement.

V. CONCLUDING REMARKS

It has been shown that a relatively simple three-factor framework can go quite a long way to explain profit and productivity behaviour in the manufacturing sector of some major industrial countries. The factor-price profile, in particular, proved a useful and concise device for representing the short-run and long-run effects of a supply shock.[28]

The empirical analysis was of necessity confined to only part of a much wider topic. While manufacturing is in many ways a leading sector in an industrial economy, it accounts for less than half of employment and output. It is an open question whether the argument presented here would also apply to other sectors or to the economy as a whole. Manufacturing, more than any other sector, is a heavy user of raw materials whose relative price has increased. It is likely that a similar argument on a smaller scale would work for the explanation of productivity slowdown in transport, agriculture, and construction. The bulk of the service sector is immune from these shifts, but it is a sector with inherently low productivity growth. A shift from manufacturing into services might thus reduce the average productivity growth of the economy as a whole but moderate the employment consequences which have not been discussed here (see Hudson and Jorsenson [1978]). More detailed work has to be done on a sector breakdown before an aggregate productivity story can be told. It would similarly be worthwhile to take a disaggregate look within the black box of the manufacturing sector to check the aggregate hypothesis (especially since the measure of aggregate output may be problematic). One could then also find out to what extent such findings can be ascribed to analogous substitutability within industries or to compositional shifts among the component parts.

Another aspect of the underlying model that has been ignored in the present empirical study is the repercussions of the profit squeeze on investment behaviour and the growth path of the capital stock. Part of the slowdown attributed to the capital input is a delayed response to the profit squeeze which in turn can be related back to the material price increase. On the other hand, induced innovation in energy-saving equipment[29] may eventually work in the other direction. Finally, the present empirical analysis has virtually avoided discussing the role of the demand side in short-run output and productivity fluctuations. This is indirectly related to the materials price hike both through terms-of-trade effects on real income and through the induced response on balance of payments and stabilization policies.

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[1]See Arrow [1974] and Bruno [1978]. Note that Y measures real income but not the real net output of labour and capital for which a Divisia index is required (see below).

[2]This expression for the factor-price frontier can be obtained from the dual profit function or more directly by subtracting the quantity expression (4) from the identity $\dot{q} = \alpha(\dot{w}_p + \dot{\ell}) + \beta(\dot{\pi}_n + \dot{n}) + \gamma(\dot{r} + \dot{k})$. The latter, in turn, is obtained from logarithmic time differentiation of $Q = W_pL + \Pi_nN + RK$.

[3]*Proof.* The distance BA can be worked out from the elasticity $(\Pi_e/R)(\Delta R/\Delta\Pi_e) = -\beta_e/\gamma = -\Pi_e E/RK$, which implies $BA = \Delta R = -(E/K)(\Delta\Pi_e)$, where E/K is measured at A. But this is the same as the shift from F_0 to F', since in that case $E/K = \eta =$ constant. The tangent to F' at B is parallel to the tangent to F_0 at A and must by definition be less steep than the tangent to F_1 at B. The rest of the argument follows by continuity.

[4]The marginal product of the fixed-proportions bundle (K,E) stays the same $(R + \eta\Pi_e)$.

[5]This point was raised by Tobin [1979] in his discussion of Bruno and Sachs [1979]. In the present empirical application to the manufacturing sector, we shall confine ourselves to the assumption of overall material separability, since the energy input is dominated by the very much (between 10 and 15 times) larger input of other raw materials and intermediate inputs (see below).

[6]One can draw the factor-price frontier for additional sectors in the same framework as Figure I. This and other extensions are taken up in a separate paper (Bruno [1981]).

[7]A general equilibrium analysis of the effects of raw materials prices on macroeconomic adjustment is given in Bruno and Sachs [1979].

[8]Germany was also able to lay off more of its transient labor force (see large drop in man-hours (panel 4) (which also shows in actual employment, not reproduced here). The two facts are probably not disconnected (see below).

[9]Kravis and Lipsey's main contribution lies in showing that the properly measured index of manufacturing exports has grown by much less during the 1970s than the commonly used unit value index. Consideration of the domestic relative wholesale prices seems to bear out their contention. For recent detailed studies of primary commodity prices in the 1970s, see Panić [1981], Bosworth and Lawrence [1982].

[10]The use of translog production functions was pioneered by Jorgenson and his associates (see Christensen *et al.* [1973]). For its application to the input of energy and raw materials, see Berndt and Wood [1979]. Their estimates may be interpreted to suggest that a Cobb-Douglas specification for K and L and the separability assumption for the non-energy material input may be close approximations. Similar results were recently obtained in a study for Japan (Lipton [1981]).

[11] In the Harper and Norsworthy [1980] data for U.S. manufacturing, also reported in Berndt [1980], the energy share by 1977 was estimated at only 2.5%, compared with 63% for all other intermediate inputs. Data compiled for the U.K. by Louis Dicks-Mireaux and used in Bruno and Sachs [1981] give these figures as 3.3% and 61%, respectively, in 1977. Of the 61% share of other intermediate inputs, roughly one-half (i.e., about 30%) are from outside manufacturing, so that the ratio is at least 10 to 1.

[12] Only the U.S. and possibly Japan (see Lipton [1981]) lend themselves to a more sophisticated approach.

[13] A more general two-level CES function is discussed and applied to U.K. data in Bruno and Sachs [1981]. There we also take a more comprehensive view of the underlying set of profit and factor demand equations.

[14] This term is $-1/2\pi_n^2(\beta/\gamma)(1 - \sigma)/(1 - \beta)$ and must be added on the right-hand side of (6). In the estimates this turned out to be insignificant.

[15] For a detailed discussion of the different patterns of wage behaviour after the oil shock, see Bruno and Sachs [1979].

[16] A partial regression of the FPF on the observations up to 1972 also yields a strong negative coefficient for Π_n (the same is true of the United Kingdom).

[17] We had no direct updated estimate for the observed R in U.S. manufacturing for 1979-80, but judging by the published estimates of total corporate profits, the direction and approximate size of movement seem right.

[18] This regression is: $r = 0.017t - 1.011w_p - 1.526\pi_n + 3.490j'$ (the standard errors of the coefficients are respectively 0.026, 0.985, 0.477 and 0.508). This is not surprising in view of the fact that j and j' are very highly correlated. The estimated elasticity of j with respect to j' is 0.171 (±0.030) which is consistent with the fact that the elasticity of r with

respect to j' turns out to be 0.18 times that of the j coefficient [see column (1) in Table II]. The capital utilization rate, J', fluctuates at a much higher amplitude than J, but its estimated effect on R is the same.

[19]The outer curve corresponds to the minimum level of the index, reached in 1972, and the inner curve corresponds to the maximum, reached in 1974, only two years apart.

[20]If the FPF is drawn in a detrended form, the percentage fall in real income per unit of labour, $\dot{y} - \dot{\ell}$ (in Figure I this would be approximated by the relative drop TM/OM), is equal to $(1 - \beta)^{-1}\beta\pi_n$. Thus the fall is gross output per unit of labour, at given capital labour ratio, is only a σ-portion of the relative distance TM/OM (usually $0 < \sigma \leq 1$).

[21]If σ_{kn} is the Allen-Uzawa partial elasticity of substitution and s_n is the material share, one can get a rough estimate of σ from $s_n(\sigma_{kn} - \sigma_{nn})$, the components of which are obtained from a translog model. The U.S. estimate is based on Berndt and Wood (1979) for the year 1971. The Japanese numbers are obtained from Lipton [1981], Tables 1.1 and 1.5, for alternative models as well as "short-period" (1955-1972) and "long-period" (1955-1978) average estimates. The U.K. (1956-1978) and German (1961-1976) estimates are obtained from a two-level CES production function model in Bruno and Sachs [1981].

[22]This form was chosen after testing the level regressions for serial/correlation and finding $\rho \sim 0$ for the FPF and $\rho \sim 1$ for productivity.

[23]In the case of the U.S., the implied time-shift factor of the two equations is significantly different, indicating a possible inconsistency of the sets of data used. On the other hand, the first U.S. regression was run with a cross-equation constraint on the coefficients of the j term. This can be worked out on the assumption that any deviation of actual from planned output is linearly related to j and that for such deviations labour and materials are used in fixed proportions.

[24]We did try one additional direct check by using input share data obtained from the BLS (Norsworthy and Harper [1979]). Regressing the share $(\pi_n + n - q)$ on π_n (as well as j) for the period 1958-1977 gave an elasticity of 0.672 (±0.042) or 0.86 (±0.059) when serial correlation was allowed for.

[25]For a statement of the measurement bias in the more general case, see Bruno [1978].

[26]Note that (10) and (11) are the same when $\Pi_n = 1$. This would happen when double deflation is done with a continuously shifting base year, which amounts to the use of a Divisia index.

[27]This is the base period used in the BLS data for the United States.

[28]It may be worth pointing out that the FPF framework would also be relevant if the productivity shock had partly come from another source.

[29]The view that the productivity slowdown can be ascribed to capital becoming obsolescent at the new energy prices, such as recently suggested by Baily [1981], is in some sense complementary to the argument proposed in the present paper.

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Table I

Rate of Change of Selected Variables, Manufacturing Sector: 1955-1980

	United States	United Kingdom	Germany	Japan
	(compounded annual rate, percent)			
1. *Gross output,*[a] *Q*				
1955-1972	4.3	2.7	6.0	13.6
1972-1975	-0.7	0	-0.6	3.3
1975-1978	7.8	1.4	3.8	9.1
1978-1980	0.4	-5.0	2.6	7.5
2. *Output per man-hour, Q/L*				
1955-1972	3.6	3.5	5.8	9.2
1972-1975	1.4	0.7	4.7	2.3
1975-1978	3.7	1.4	5.0	8.0
1978-1980	1.5	0.6	2.7	6.9
3. *Capital stock per man-hour, K/L*				
1955-1972	2.0	4.9	6.7	6.7
1972-1975	4.2	3.1	9.5	13.3
1975-1978	-1.2	1.8	3.1[b]	5.5[b]
1978-1980	4.4	7.9	..	..
4. *Man-hours, L*				
1955-1972	0.7	-0.8	0.2	4.0
1972-1975	-2.1	-0.7	-5.3	-2.8
1975-1978	4.1	0	-1.2	1.1
1978-1980	-1.1	-5.6	-0.1	0.6
5. *Relative price of material inputs,* Π_n *(Index 1971 = 100), selected years*				
1955	112	122	111	93[c]
1971	100	100	100	100
1974	131	147	109	158
1978	122	131	100	125
1980	128	140	110	149[d]

Table I (cont'd). Rate of Change of Selected Variables, Manufacturing Sector: 1955-1980

	United States	United Kingdom	Germany	Japan
	(compounded annual rate, percent)			
6. *Product wage,* W_p				
1955-1972	3.0	4.3	8.4	11.4
1972-1975	-1.9	3.7	5.8	7.9
1975-1978	2.2	-0.2	5.6	6.3
1978-1980	-1.8	4.4	..	..
7. *Rate of profit in manufacturing, R, selected years (percent)*[e]				
1965	21.5	10.2	19.0	6.8[f]
1972	13.4	8.4	13.9	5.5
1975	8.7	1.9	11.7	3.7
1976	11.2	4.3	12.7	4.4
1977	12.0	5.9	..	4.5
1978	11.9	5.9	..	4.8
1980	(9.6)	(2.8)	..	..

[a] Defined as Index of gross output in manufacturing.

[b]1975-1977. [c]1956 [d]1979.

[e]These figures cannot be compared across countries. 1980 estimates are rough and preliminary. [f]1966.

Sources: Gross output (Q) [for U.S.: FRS Index of manufacturing production], Man-hours (L) [for U.S. - hours paid; for others - hours worked), and Wage rate (W): from Bureau of Labor Statistics, *International Comparisons of Manufacturing Productivity and Labor Costs--Preliminary Measures for 1980* [May 1981]. Material prices (P_n) and Wholesale prices (P): U.S., *Economic Report of the President* [1981], Tables B-55, B-56; U.K., CSO, *Economic Trends* [1980]; Japan, Bank of Japan, *Bulletin;* and Germany, OECD, *Main Economic Indicators,* various years.

Capital stock (K): Gross stock, based on estimates prepared by Artus [1977].

Rate of profit (R): U.S., from Holland and Myers [1980]; U.K., Williams [1980]; Germany, Hill [1979]; Japan, from Wakasugi *et al.* [1980].

Table II.

Factor Price Frontier: Equation (6)[a]

	United States 1955-1978		United Kingdom 1961-1977		Germany 1960-1976		Japan 1966-1978
	(1)	(2)[b]	(3)	(4)	(5)	(6)	(7)
Regression coefficients of							
t (time)	0.018	0.036	0.183	0.168	0.173	0.220	0.134
	0.016	0.022	0.065	0.072	0.063	0.070	0.073
w_p	-1.413	-2.061	-3.518	-4.994	-2.672	3.698	-1.426
	0.636	0.838	1.695	1.757	0.969	1.019	0.626
π_n	-1.177	-1.648	-2.269	-2.364	-1.910	2.902	-1.686
	0.297	0.483	0.548	0.618	0.834	0.849	0.517
j	19.001	19.347	14.035	-	2.449	-	-
	1.598	1.837	6.499		1.016		
Statistics							
$\overline{R}$	0.91	0.89	0.83	0.78	0.91	0.88	0.78
DW	1.97	2.04	2.21	2.29	1.37	1.80	1.25
SE	0.08	0.09	0.21	0.24	0.05	0.06	0.14
Estimated parameters[c]							
λ	0.016	0.019	0.031	0.034	0.057	0.059	0.094
$\gamma/(1-\beta)$	0.414	0.326	0.221	0.167	0.272	0.213	0.407
β	0.328	0.350	0.334	0.283	0.342	0.382	0.410

[a]Small numerals are standard errors. See Table I stubs for explanation of symbols.

[b]Column (2) is a two-stage least-squares variant.

[c]λ is corrected for time trend of j.

Table III.

Estimates of Production Parameters[a]

	United States			United Kingdom			Germany			Japan		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	1957-1980		59-72	57-80	1957-1978		1961-1976			66-78	58-78	61-77
λ_F	0.019 0.001	0.018 0.001	-	0.032 0.002	0.028 0.008	0.027 0.005	0.059 0.003	0.057 0.003	0.061 0.003	0.102 0.010	0.121 0.006	0.090 0.023
λ_Q	0.037 0.004	0.036 0.007	0.033 0.012						0.045 0.004		0.096 0.023	
ϕ	0.249 0.036	0.265 0.031	(0.33)	0.156 0.034	(0.22)	(0.22)	0.218 0.048	0.197 0.041	0.186 0.035	0.431 0.090	0.439 0.094	(0.40)
β	0.327 0.030	0.278 0.029	(0.35)	0.253 0.037	(0.33)	(0.33)	0.379 0.047	0.396 0.042	0.366 0.044	0.444 0.049	0.498 0.043	(0.41)
$\delta(j)$	16.978 1.720	19.324 1.530	-	(0)	-	-	..	..	..	(0)	(0)	(0)
$\theta(j)$	2.930 0.291	(0)	2.16 0.40	(0)	(0)	0.89 0.46	0.854 0.219	(0)	(0)	(0)	(0)	(0)
σ	-0.216 0.109	0.196 0.214	0.57 0.24	0.337 0.189	0.46 0.18	0.35 0.15	0.132 0.229	0.472 0.287	0.649 0.281	0.812 0.214	0.756 0.212	0.91 0.29
Statistics												
SE F	0.095	0.080	-	0.201	-	-	0.056	0.067	0.054	0.119	0.132	-
SE Q	0.014	0.026	0.01	0.023	0.02	0.02	0.013	0.018	0.015	0.045	0.057	0.049
DW F	2.07	2.22	-	1.76	-	-	1.76	1.84	1.82	1.14	0.87	-
DW Q	2.44	2.07	1.75	1.40	1.74	1.58	2.40	1.41	2.04	1.33	1.54	1.88
Method of Estimation[b]	2	2	1(ρ)	2+I	1(ρ)	1	2+I			2	2	1(ρ)

Notes on table:

[a] Small numbers are standard errors. Numbers in round brackets are assumed coefficients. (..) implies highly insignificant. (-) not estimated.

[b] 1 = single equation OLS, 1(ρ) = corrected for autocorrelation.
2 = joint regression using FIML, 2+I = FIML + use of instrumental variables

Table IV

Estimated Components of Productivity Slowdown

(average logarithmic rate of change)

	United States	United Kingdom	Germany	Japan
Average rate of change of output (Δq)				
1. 1960s[a]	5.2	3.2	5.8	12.3
2. 1970s[b]	2.7	2.1	1.2	4.6
3. Average deceleration of output (1. *less* 2.)	2.5	5.3	4.6	7.7
Of which:				
4. Labour input, L	0.6	1.8	3.1	2.4
5. Capital input, K	0.0	0.3	0.8	2.0
6. Cyclical factor[c]	0.4	0.4	0.2	-
Productivity slowdown				
7. (3. *less* 4., 5., 6.)	1.5	2.8	0.5	3.3
Raw materials price change				
8. Unweighted ($\Delta\dot{\pi}_n$)	3.8	5.7	2.7	6.6
9. Weighted[d]	1.9	3.1	1.6	4.6
"Implied" value of σ under full accounting (7:9)	0.8	0.9	0.3	0.7

[a]United States, 1959-1972; United Kingdom and Japan, 1958-1973; Germany, 1960-1973.

[b]United States, 1973-1980; United Kingdom, 1974-1980; Japan, 1974-1978; and Germany, 1974-1977.

[c]Estimated effect of j (weekly hours) from a regression for the pre-1973 period.

[d]This is $(1 - \beta)^{-1}\beta(\Delta\dot{\pi}_n)$ using β estimates from FPF regressions.

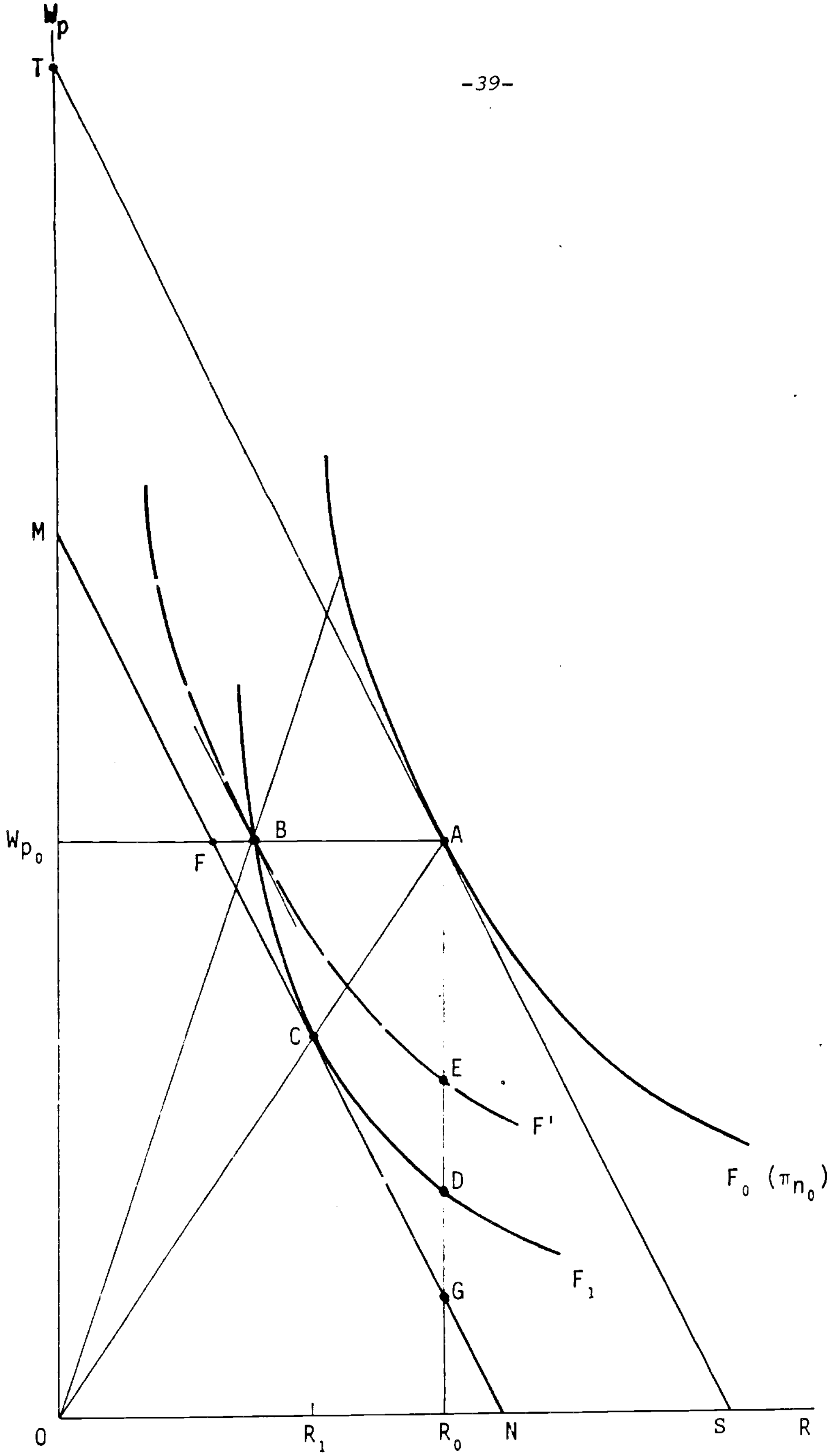


Figure I

Figure II

Relative Input Price in Manufacturing 1955-80, four major industrial countries and the relative world price of primary exports (Kravis-Lipsey)

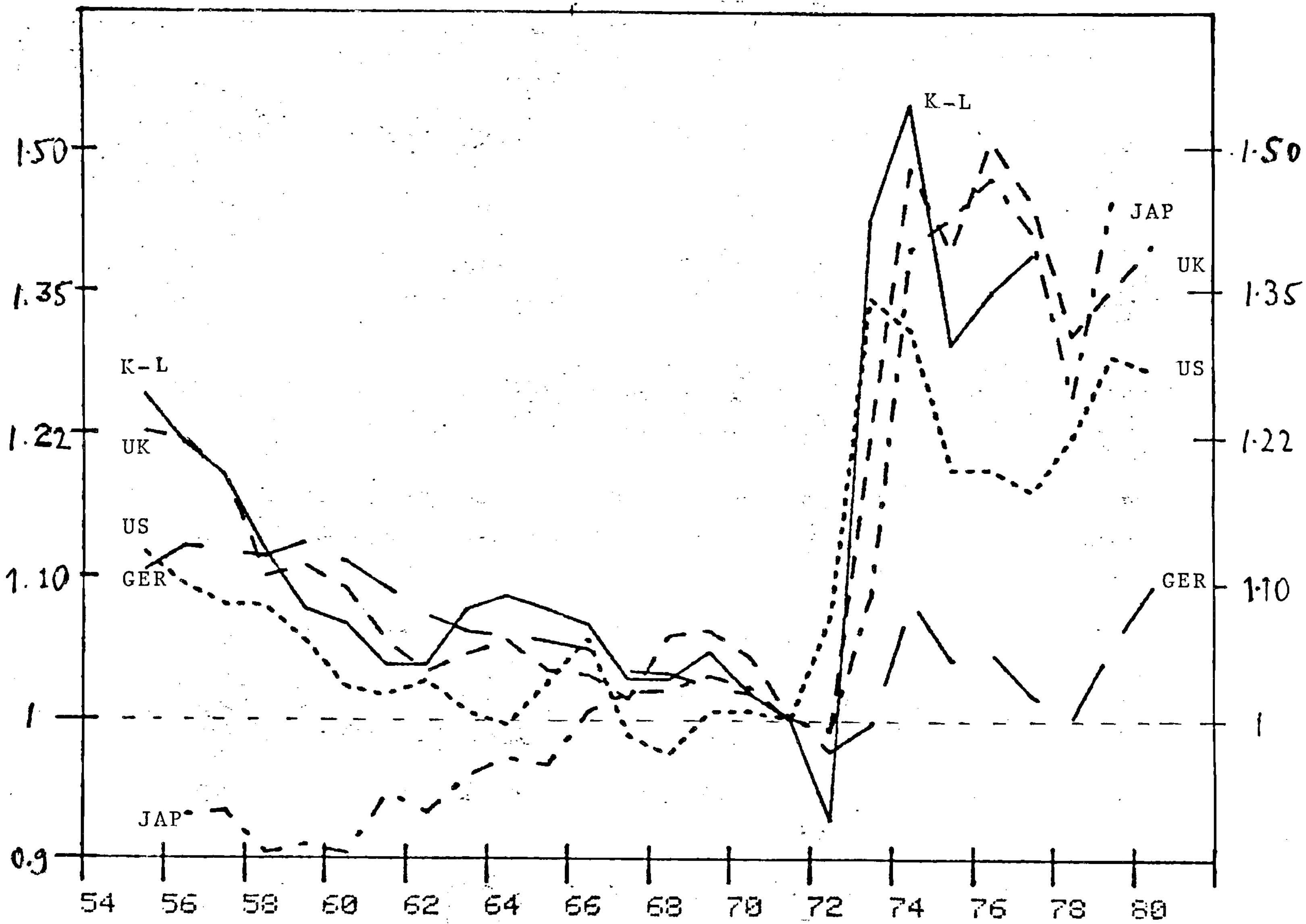


Figure III

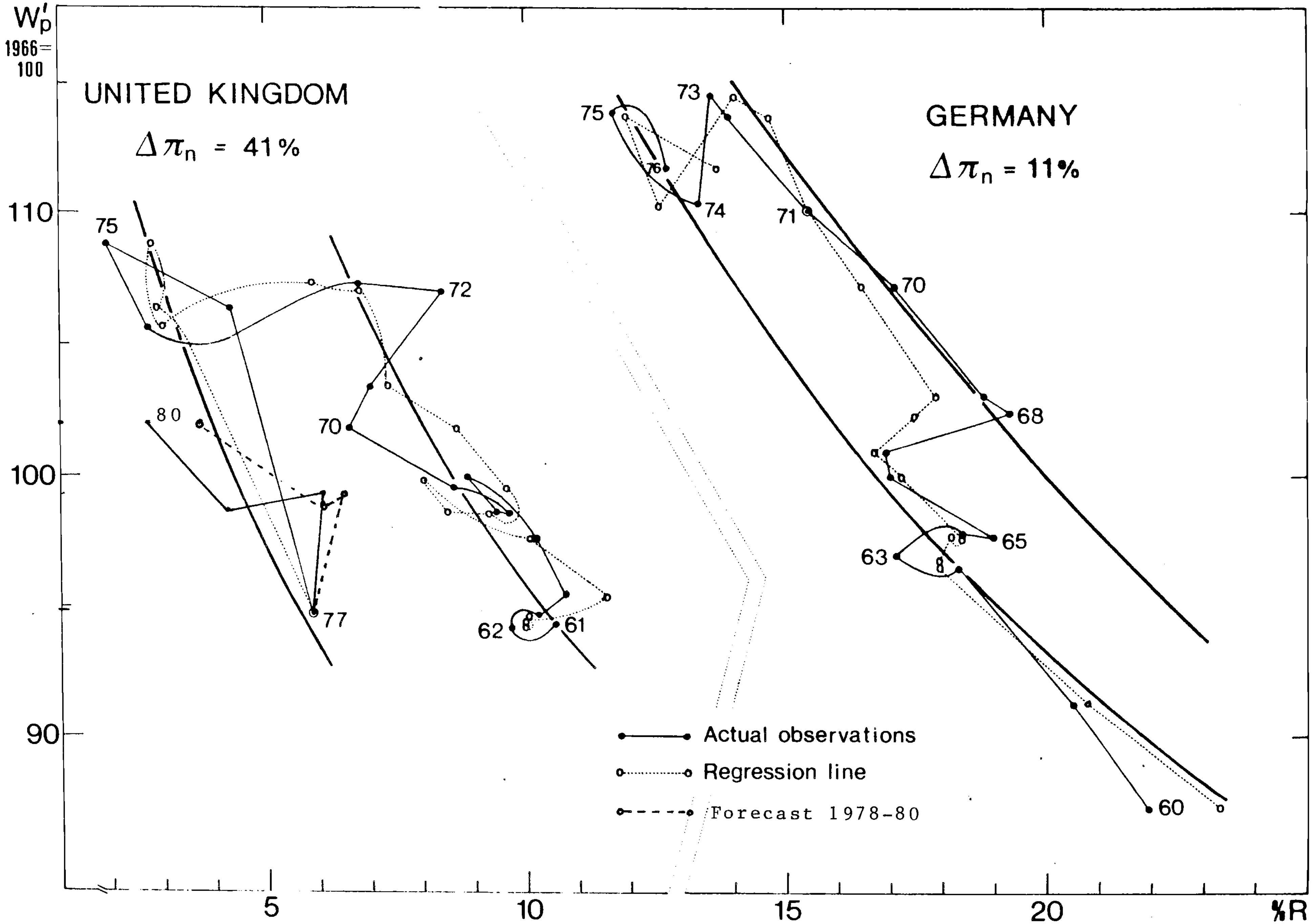
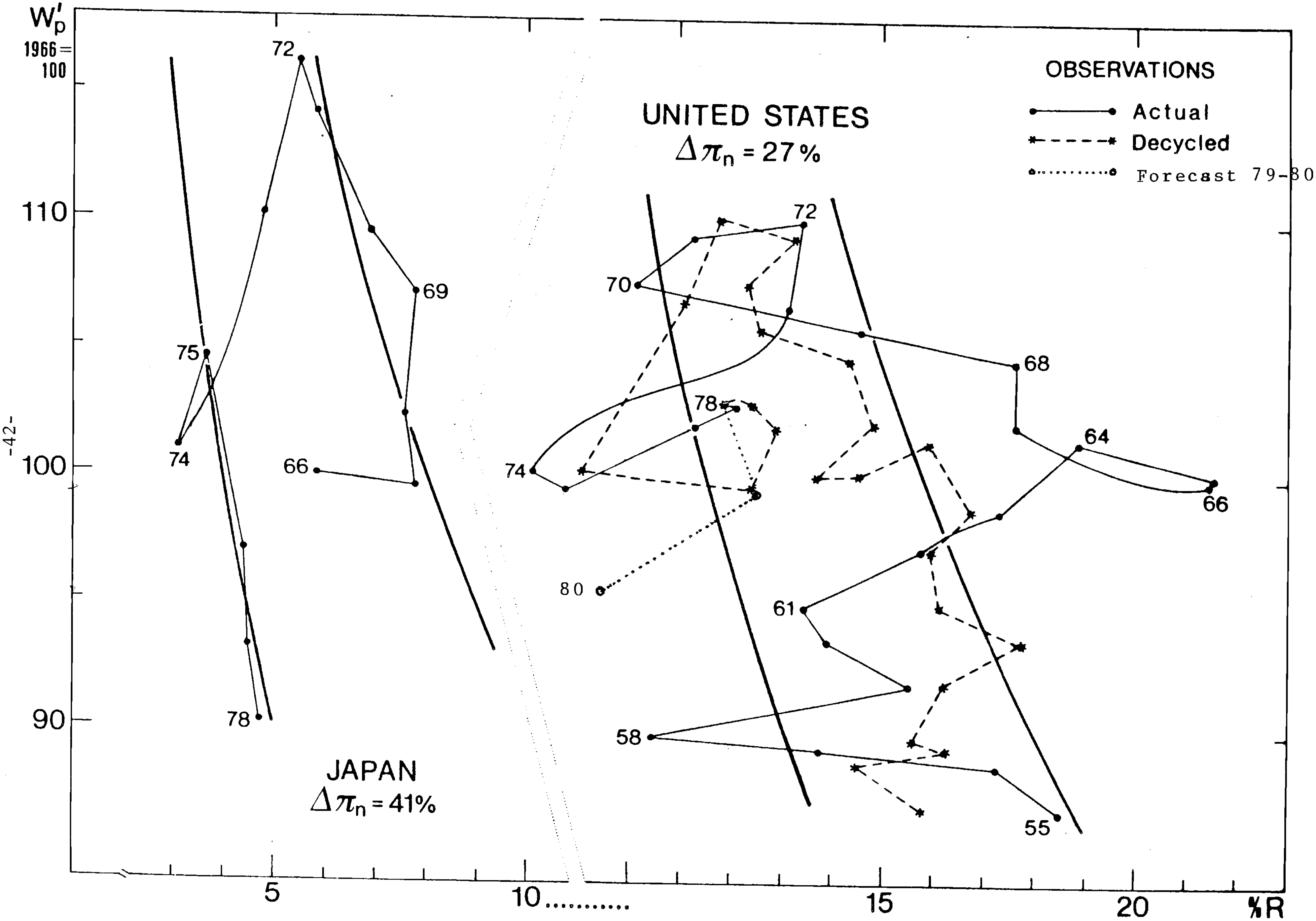

W'p 1966=100
UNITED KINGDOM
$\Delta \pi_n$ = 41%
GERMANY
$\Delta \pi_n$ = 11%
110
100
90
5
10
15
20
%R
75
72
70
80
77
62
61
73
75
76
74
71
70
68
65
63
60
Actual observations
Regression line
Forecast 1978-80

Figure IV


W'p
1966=
100
110
100
90
5
10
15
20
%R
72
75
74
78
66
69
JAPAN
$\Delta\pi_n = 41\%$
UNITED STATES
$\Delta\pi_n = 27\%$
OBSERVATIONS
Actual
Decycled
Forecast 79-80
70
68
64
80
61
58
55