Proc. Natl. Acad. Sci. USA
Vol. 80, pp. 4561–4568, July 1983
Review

International productivity comparisons (A Review)

(competitiveness/unit cost efficiency)

L. R. KLEIN

Department of Economics, University of Pennsylvania, Philadelphia, Pennsylvania 19104

Contributed by Lawrence Klein, April 8, 1983

MEANING OF PRODUCTIVITY

According to the *Oxford English Dictionary* (1), *productivity* is equated to *productiveness*,* which, in turn, is defined as ". . . fruitfulness; abundance or richness in output." Solomon Fabricant, writing in the *Encyclopedia of the Social Sciences* (3), states, ". . . productivity measures the fruitfulness of human labor . . . In another sense, productivity measures the efficiency with which resources as a whole including capital as well as manpower are employed in production."

In these general terms, productivity carries a meaning that is fairly well known, in an intuitive sense, to most people and is, by and large, a good thing, something to be encouraged and desired. There are those, however, who fear productivity to the extent that it might lead to displacement from work. This is the case in which productivity enhancement comes about through technological progress.

Nonparametric Measurement. Productivity, as I shall use the term in this essay, has a technical meaning that is obviously tied to the dictionary meaning. I shall look at productivity in two ways, nonparametrically and parametrically.

In a nonparametric sense, I shall define productivity as some simple ratio, but with common-sense meaning:

$$X/L = \text{labor productivity},$$

where X = output and L = labor input, and

$$X/TF = \text{total factor productivity},$$

where $TF = L + (r/w)K$, r = capital rental, w = wage rate, and K = capital stock.

These two key ratios for labor and for total factor productivity seem to be simple enough, but in careful measurement for quantitative economics each numerator and denominator requires precise specification.

If an economic establishment—firm, plant, enterprise—produces a single output, X is best measured as the physical number of units produced in a given period of time such as a week, month, quarter, semester, year, quinquennium, or decade. The usual time unit is 1 year, but that choice is not unique.

Most establishments produce more than one product; therefore, measurement in physical units becomes awkward. Of the many common denominators that may be used to measure X, the most natural one for an economist to use is money value, such as dollars of production in the case of the United States. This choice is not without its problems, however, because money values change rapidly, especially in an era of inflation; therefore, the money value of X must be expressed in *constant* prices. The present convention in the United States is to measure real output in terms of 1972 dollars. This means that the components of X are all valued in terms of the average price prevailing during 1972 and added to strike a total for each year, in this fixed price system.

In the case of a single establishment, it is easy enough and understandable to use gross output in obtaining the constant price value of output. This is obtained by valuing each physical unit produced in terms of the price of that unit in 1972. When we move to consideration of productivity for a larger aggregate such as all manufacturing or the entire national economy, we must face the situation that the output of one establishment (sector) is the input of another establishment (sector). To avoid multiple counting, we measure X as *value added.* This is the value of gross output *less* the value of intermediate input. The latter are materials and energy used in the production process.

From an accounting point of view, there is no problem in subtracting the value of intermediate inputs from the value of gross output. It is more of a problem to define, conceptually, real value added—i.e., constant-priced gross output less constant-priced intermediate inputs (4). The prices appropriate to output and input are different; therefore, the concept of real value added may not bear a clear and simple relationship to nominal (current-priced) value added.

Economic magnitudes, in general, should satisfy the identity relationship

$$\text{price} * \text{quantity} = \text{value}.$$

If we define the price of real value added as the ratio of nominal value added to real value added, then the identity is satisfied; however, this ratio may define a peculiar or unusual price index that does not have the structure or performance of conventional price indexes.

For the economy as a whole, total value added is synonymous with the concept of gross national product (GNP), and a price index for total GNP can be constructed in terms of the prices of the end products, the final purchases of goods and services, each of which has a definite quoted or implied price. It is somewhat clearer how to define real GNP, or total value added, but it is less clear for a sector of the economy, such as a particular industry. The numerator of the productivity ratio is thus more uncertain if the value added rather than the gross output concept is used. My preference would be to use the concept of real gross output for the sector productivity ratio and the concept of value added for the economy-wide productivity ratio. At the sector level, productivity would be measured in such concepts as output of steel tonnage, grain bushels, cement tonnage, vehicles, or their real gross output value in multiproduct activities per unit of input. The choice of the numerator of the seemingly straightforward productivity ratio is thus

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. §1734 solely to indicate this fact.

Abbreviations: GNP, gross national product; GDP, gross domestic product; CES, constant elasticity of substitution.

* "To increase the productiveness of labour is really the important thing for everybody"; see ref. 2.

by no means obvious; the problem of the choice of the denominator is even more complicated. Consider first, the concept of labor productivity. The consideration of this measure does not mean that labor is the only productive input; it simply means that we are trying to calculate values for a conventional nonparametric statistic, the ratio of real output to real labor input.

Two obvious choices for the (labor input) denominator are number of persons employed and number of hours worked. The latter is obtained as the product of the number of persons and the average number of hours worked per week, multiplied by 52. It seems obvious that hours worked provides a better measure of labor input than does number of employees, but the problem is that information on the working week or any other indicator of average hours worked is often lacking. This is especially true in making international comparisons. For the United States and many other industrial countries, statistics of workers employed and hours worked are generally available on a total and sectoral basis, but this is definitely not the case in many developing or centrally planned economies. If the latter areas are to be examined in the context of international comparisons, then the best *common denominator* may be number of persons working rather than number of hours worked.

Regardless of the resolution of the choice between a count of employees or hours worked, there is another problem—namely, with the implicit assumption that all workers are of the same quality. In the first place, there are distinctions between the contributions of production workers and overhead (nonproduction) workers. Similarly, there are great differences in worker skill, training, and education. Weighted averages of inputs of skill equivalents would be an appropriate denominator. To the extent that relative wage rates represent relative marginal (incremental) productivities, the weights can be readily computed from available data, as in

$$L_1 + (w_2/w_1)L_2 + (w_3/w_1)L_3 + \ldots + (w_n/w_1)L_n.$$

This makes the unit of measurement the productivity equivalent of labor type (i.e., 1) and weights other labor types by their wage rate relative to that of type 1 (w_1). The choice of the *numéraire* type has no bearing on the movement of productivity but measures the level of productivity in terms of one single labor type. An average type could also be used, as in

$$(w_1/\overline{w})L_1 + (w_2/\overline{w})L_2 + \ldots + (w_n/\overline{w})L_n$$

$$\overline{w} = 1/n \sum_{i=1}^{n} w_i.$$

Average wage could be computed as either a weighted or an unweighted average.

All the problems in selecting an appropriate denominator for the labor productivity ratio are more serious and more complicated in choosing the denominator for the total factor productivity ratio. Total factor input for the economy as a whole is defined as a weighted combination of labor and capital inputs. This weighted sum would be appropriate for a ratio that has real value added in the numerator. For a gross output numerator, it makes more sense to include intermediate factor inputs, associated with the particular sector whose productivity is being estimated, together with the traditional value-added factors—labor and capital.

In estimating total factor inputs, there is not only the perplexing question of developing labor and capital weights but also the problem of estimating capital itself. Total factor input has been defined as

$$TF = L + (r/w)K.$$

This is just the same as the approach suggested for combining labor of different skill levels. The various kinds of labor were aggregated as a linear combination with weights equal to relative wage rates. Here we form a linear combination of the two factors with weights being their relative factor prices. For many years in railway engineering–economic studies, traffic units were used, as a combination of passenger miles and freight ton miles. The combination was

$$\text{ton miles} + 2.4(\text{passenger miles}) = \text{traffic units},$$

where the coefficient is the long-run relative price of a passenger mile to a ton mile. For a railway productivity study, this could be used as a gross output measure, where the railway system provided joint (multiple) outputs.

In the productivity literature, we often find total factor input defined as

$$\frac{wL}{wL + rK}L + \frac{rK}{wL + rK}K.$$

The weights are factor shares in total value added. If L and K are index values on bases L_0 and K_0, and if the weights are base-period shares, then this weighting scheme, except for normalization, is equivalent to that introduced above because the ratio between the weights is r_0/w_0.

Total factor productivity could be extended to cover not only aggregate labor and capital inputs but also types of labor input, types of capital input, energy inputs, and materials inputs. This part of the problem needs explanation and research analysis but is solvable in a satisfactory way. More serious problems exist in the measurement of capital. Capital is made up of productive equipment, machinery, rolling stock, tools, buildings, right-of-way, physical facilities, and other structures. These are difficult to combine because their relative prices are not readily available or even ascertainable. Capital deteriorates, destructs, and obsolesces. The measurement of capital consumption is inherently difficult, and data are relatively sparse. Life tables for physical capital are not comprehensive, as they are for human capital. There are measures of capital consumption, but they are known to be imperfect and are often distorted deliberately for tax purposes. Given all these thorny problems, economic statisticians try to measure capital according to the recursive formula

$$K_t = K_{t-1} + I_t - D_t,$$

where K_t = end of period stock of capital, I_t = gross real outlays on capital during t, and D_t = capital consumption during t. To work through this formula, it is necessary to have a starting value as an initial condition. A formula for computing D_t is also needed.

Even after statistical series for K_t have been prepared, after taking all the perilous steps discussed above, there is a further problem. This formula gives capital (stock) in existence but what we need to know for productivity measurement is capital in use, either as a flow of use or as the stock value that was actually used. This requires being able to distinguish between idle and active capital or to obtain statistics of capital utilization. Usually only fragmentary data are available for such concepts as (*i*) idle shipping tonnage, (*ii*) number of shifts worked, (*iii*) idle rail cars, and (*iv*) occupancy rate of buildings. These help, but are fragmentary. Labor inputs are measured by labor actually used, either as hours worked or people at work. No corresponding information about capital is available on a general basis.

Parametric Measurement. The concept of a technical production function is central to economic analysis. The meaning of a production function, as this concept is used in economics, is a physical relationship between inputs and outputs of an economic process. It has clearest meaning when applied to the production process for a given establishment, but it is used on a wider scale for industries, sectors, or whole national economies.

At the specific level, it is meant to show the laws of engineering and science that serve as constraints on economic activity. It should not involve prices or market phenomena that are typical for economic analysis, but it should affect the outcome of economic analysis. The flow of gas through a pipeline is one of the clearest concepts of a production function. The gas, the pipeline capital, and the physical conditions within the pipe are the inputs. The flow of gas to users is the output. The output flow is governed by the laws of gases.

There is less specificity at a higher level of aggregation. Conceptually, there are catalogues of inputs and outputs for the whole national economy but, statistically, we proceed at a much more general level and assume that the following relationship holds

$$X = F(K, L, E, M, t) + e,$$

where X = total production, K = total capital input, L = employment, E = energy, M = materials, t = chronological time, and e = error. Part of the error term may be associated with the use of aggregative indexes to measure the various inputs and outputs at a level beyond the individual establishment. As in the discussion of nonparametric methods, distinctions can be made among types of capital, labor, materials, and energy, not to mention the fact that there will be multiple outputs too.

Because intermediate inputs, E and M, are used on the right-hand-side to explain fluctuations in X, this output variable must also include intermediate inputs; therefore, X is truly gross output and not a value-added concept such as gross domestic product (GDP) or GNP.

The problems of capital measurement associated with distinctions between the stock of capital in existence and the flow of capital services used apply here as well as in nonparametric measurement.

The production function is written here in very general terms. In practice, some very specific forms are conventionally used. The most celebrated, following the pioneering research of Paul Douglas, is the Cobb–Douglas function, linear in the logarithms of output and inputs

$$X = A\, K^{\alpha} L^{\beta} E^{\gamma} M^{\delta} \exp(\rho t) e_t.$$

The error is made multiplicative in this expression and is additive in the logarithmic transformation. An indicator of technical progress is ρ, the instantaneous rate of improvement that comes about separately from changed inputs of *KLEM*.

A second form is called the constant elasticity of substitution specification (CES). The elasticity of substitution between input pairs is unity for the Cobb–Douglas case. It is constant but not necessarily equal to unity for the CES case. An extended CES function is

$$X = A(\delta_K K^{-\rho} + \delta_L L^{-\rho} + \delta_E E^{-\rho} + \delta_M M^{-\rho})^{-1/\rho} \exp(\rho t) e_t.$$

The disadvantage of this production formula is that the elasticity of substitution is exactly the same for every pair of inputs. To generalize the concepts used here, we have designed the nested CES function as

$$X = A\Big(\theta\{\eta[\delta K^{-\rho_1} + (1-\delta)E^{-\rho_1}]^{\rho_2/\rho_1} + (1-\eta)L^{-\rho_2}\}^{\rho_3/\rho_2} + (1-\theta)M^{-\rho_3}\Big)^{-1/\rho_3} \exp(\rho t) e_t.$$

In this separable specification, there is first a nested CES combination of capital (K) and energy (E). Then we obtain a relationship between a capital–energy combination and labor input. Finally we combine *KEL* (capital–energy–labor) into one single input and estimate the elasticity of substitution between a *KEL* combination and M. As in the Cobb–Douglas case, there is provision for a multiplicative error term, but in a logarithmic transformation the error term is additive as is the rate of technical improvement.

A translog production function is a logarithmic function for $\ln X$, which is quadratic in the logarithms of the inputs. This kind of function has a great many parameters but can be transformed into simple expressions in cost shares and linear functions of input prices.

Finally, there could be general linear functions or functions that are linear with pairs in fixed proportions.

A fundamental equation for productivity analysis is

$$\frac{d\ln X}{dt} = \frac{1}{F}\left(\frac{K\partial F}{\partial K}\frac{d\ln K}{dt} + \frac{L\partial F}{\partial L}\frac{d\ln L}{dt} + \frac{E\partial F}{\partial E}\frac{d\ln E}{dt} + \frac{M\partial F}{\partial M}\frac{d\ln M}{dt} + \frac{\partial F}{\partial t}\right).$$

This expresses the rate of change (approximately the finite-step percentage change) of output as a weighted sum of the rates of change of the factor inputs (*KLEM*) and the time rate of growth of the whole function. In the Cobb–Douglas or CES specifications with a multiplicative time factor, the rate of change of the trend term is a constant.

In a special case of the Cobb–Douglas function, a conventional workhorse for the design of productivity and other output calculations, we assume

$$\alpha + \beta + \gamma + \delta = 1,$$

which implies constant returns to scale. If all four inputs are scaled by the factor λ, then the whole function and output are also scaled by the same factor. We call this homogeneity of degree one in the input values. In this case, we can write

$$\frac{X}{L} = A\left(\frac{K}{L}\right)^{\alpha}\left(\frac{E}{L}\right)^{\gamma}\left(\frac{M}{L}\right)^{\delta}\exp(\rho t)e_t$$

$$\frac{d\ln(X/L)}{dt} = \alpha\frac{d\ln(K/L)}{dt} + \gamma\frac{d\ln(E/L)}{dt} + \delta\frac{d\ln(M/L)}{dt} + \rho + \frac{d\ln e_t}{dt}.$$

With this parametric specification, the rate of growth of labor productivity is a linear function of the growth rate of labor–factor ratios (called factor intensities) and technical progress, which measures, in a parametric sense, total factor productivity.

The parameters of the Cobb–Douglas function are the weights for combining the growth of factor intensities, and the technical progress factor is a direct estimate of total factor productivity; this is the meaning of a parametric approach.

This approach could be used with production functions in general. If they are homogeneous of degree one in the several inputs and multiplied by an exponential factor

$$\exp(\rho t),$$

then we have

$$X/L = F(K/L,\, E/L,\, M/L)\exp(\rho t)e_t$$

and

$$\frac{d\ln(X/L)}{dt} = \frac{(K/L)\,F_{K/L}}{F}\frac{d\ln(K/L)}{dt} + \frac{(E/L)\,F_{E/L}}{F}\frac{d\ln(E/L)}{dt} + \frac{(M/L)\,F_{M/L}}{F}\frac{d\ln(M/L)}{dt} + \rho + \frac{d\ln e_t}{dt}.$$

Once the parameters of F are determined, the partial derivatives

$$\frac{\partial F}{\partial K} = F_K; \quad \frac{\partial F}{\partial E} = F_E; \quad \frac{\partial F}{\partial M} = F_M$$

can be evaluated. They need not be constant or proportional to F, as in the Cobb–Douglas case.

If we introduce some economic theory into the specifications, we have the conditions that each productive factor is paid a unit price (cost) equal to its marginal productivity

$$\frac{\partial F}{\partial L} = \frac{w}{p}; \quad \frac{\partial F}{\partial K} = \frac{r}{p}; \quad \frac{\partial F}{\partial E} = \frac{g}{p}; \quad \frac{\partial F}{\partial M} = \frac{q}{p},$$

where w = wage rate, r = capital rental, g = unit energy cost, q = unit material cost, and p = output price. In the Cobb–Douglas case, these conditions are particularly simple

$$\beta = \frac{wL}{pX}; \quad \alpha = \frac{rK}{pX}; \quad \gamma = \frac{gE}{pX}; \quad \delta = \frac{qM}{pX}.$$

We can accordingly write

$$\frac{d \ln (X/L)}{dt} = \frac{rK}{pX}\frac{d \ln (K/L)}{dt} + \frac{gE}{pX}\frac{d \ln (E/L)}{dt} + \frac{qM}{pX}\frac{d \ln (M/L)}{dt} + \rho + \frac{d \ln e_t}{dt}.$$

Here we have a correspondence with the nonparametric case, where total factor productivity, with four input factors, would be calculated as

$$\frac{d \ln (X/L)}{dt} - \frac{rK}{pX}\frac{d \ln (K/L)}{dt} - \frac{gE}{pX}\frac{d \ln (E/L)}{dt} - \frac{gM}{pX}\frac{d \ln (M/L)}{dt}$$

or the rate of growth of labor productivity less the weighted sum of rates of growth of factor intensities, the weights being factor shares. This comes, in effect, to our nonparametric measures of total factor productivity, although it is often computed with only two factors, labor and capital, and value-added output.

INTERNATIONAL MEASUREMENT

The preceding two sections define the problem and approach. I now turn to some international and other practical issues. It is important to construct reliable and indicative productivity measures for the major economies to see how each one by itself performs over the course of time. There is, however, an additional dimension that is of utmost importance—namely, the intercountry comparisons of productivity. In this field, we have questions of substance. Which countries are highly competitive and efficient, from a production point of view? There is also a methodological question of how to measure productivity reliably at the international level.

First, let us consider the methodology of measurement. The first things that must be examined are the rates of exchange among currencies. In some few cases, for particular industries, physical measures can be prepared. Tons of steel per worker and number of vehicles per worker are fairly good measures for cross-country comparisons. They are, however, relatively rare. For the economy as a whole and for most industrial sectors, physical measures are not applicable, and there must be resort to valuation comparisons.

To compare productivity across countries, the values of production, in own currency units, for each country, per worker hour (or per worker) must be converted to measures of production per worker hour (or per worker) in a common currency unit, the most frequently used case being U.S. dollars. For the major countries and for the economy as a whole, or broad sectors such as manufacturing, data are available on worker hours. At the industry level, across countries, or even at the aggregative level across smaller or developing countries, the number of workers rather than worker hours would have to be used.

Because productivity is meant to be a physical indicator, output per worker hour (or per worker) should be expressed in constant prices, which means that constant exchange rates as well as constant domestic prices would have to be used.

The most common procedure is to use market exchange rates bilaterally against the U.S. dollar; therefore, we would be considering output per worker hour (or per worker) in constant (base-period) prices at base period dollar exchange rates—i.e., at constant (base-period) U.S. dollars. For an economy-wide measure, there are few reliable statistics on worker hours, so total employment is used. In Table 1, figures are given for the industrial countries in 1980. These figures show a great disparity between Italy and the United Kingdom, on the one hand, and all the others. They also show many other countries exceeding the United States in productivity level, as of 1980. Such comparison results often occur, either per worker or per inhabitant if market exchange rates are used, but the purchasing power conversion ratios developed by Kravis *et al.* (5) show that the United States is still number one if such ratios are used in place of market rates.

If we confine our attention to rates of change of productivity or to indexes showing change over base values, then we need not convert the output measures to a common currency unit. The *changes* can be expressed in own constant-currency units; the rate of change will be insensitive to a constant factor used for currency conversion.

In a series of interesting reports, the U.S. Department of Labor has made productivity and cost comparisons across the same countries listed in Table 1, but confined to the manufacturing sector (6). In these reports, rates of change in productivity are measured in domestic currency units. By confining measures to the manufacturing sector and to the same major countries listed in Table 1, productivity changes are obtained based on estimates in own-currency units (Table 2).

The most striking thing about Table 2 is the wide pervasiveness of the world productivity slowdown. In every country examined here, the growth rate of productivity fell significantly after 1973, the time of the oil embargo. It is no surprise that the growth of Japan's manufacturing productivity was relatively high in international comparisons. But it is not so well known that Japan's growth rate slipped considerably after 1973, as did that of most other countries. The drop in the U.S. rate, how-

Table 1. Gross domestic product per worker: Selected industrial countries (1980)

	U.S. dollars		U.S. dollars
United States	18.0	Fed. Rep. of Germany	19.4
Canada	18.0	Italy	11.0
Japan	15.1	United Kingdom	10.3
Belgium	19.1	Denmark	17.4
France	18.4	Sweden	18.4
		Netherlands	20.6

Results are expressed in thousands of 1975 U.S. dollars, and 1975 exchange rates were used for currency conversion.

Table 2. Changes in manufacturing productivity

	Output per hour	
	1960–1973	1973–1981
United States	3.0	1.7
Canada	4.5	1.4
Japan	10.7	6.8
France	6.0	4.6
Fed. Rep. of Germany	5.5	4.5
Italy	6.9	3.7
United Kingdom	4.3	2.2
Belgium	7.0	6.2
Denmark	6.4	4.1
Netherlands	7.6	5.1
Sweden	6.7	2.2

Results are expressed as percent change.

ever, brought this country to almost a standstill position.

Many scholars are devoting attention to explanations for the productivity slowdown. Giersch and Wolter (7) have considered 14 different explanations of the worldwide productivity slowdown without coming to a succinct conclusion. In a parallel study, Lindbeck (8) attributes the slowdown to structural changes in the politico-economic environment and to unusually severe disturbances of the 1970s.

INTERNATIONAL COMPETITIVENESS

A principal reason for examining productivity levels or growth rates in different countries is to assess their mutual competitive positions, particularly with respect to foreign trade. Generally speaking, those countries that have shown relatively strong productivity growth have been highly competitive and have captured markets.

Competitiveness, however, depends on more than productivity; it depends on costs, profit margins, and exchange rates. At the international level, except in carefully constructed bilateral studies, total factor productivity has not been satisfactorily measured. Most of the studies have been concerned with labor productivity. At that level of investigation, the appropriate cost item is the wage rate. Statistics of unit labor cost have been carefully prepared in tabulations by the U.S. Department of Labor. Unit labor cost is computed as the wage rate divided by productivity (or the wage bill per unit of output). The growth rates in unit labor costs, measured in U.S. dollars, are given in Table 3.

It is evident from these figures that the productivity slowdown is reflected in a unit labor cost speed-up. The high wage costs, together with poor productivity growth, contribute jointly

Table 3. Changes in unit labor costs in manufacturing

	U.S. dollars	
	1960–1973	1973–1981
United States	1.9	7.7
Canada	1.9	6.5
Japan	4.9	7.2
France	2.8	9.4
Fed. Rep. of Germany	6.1	9.1
Italy	5.4	8.1
United Kingdom	2.6	15.0
Belgium	4.6	8.6
Denmark	5.0	7.7
Netherlands	6.1	8.0
Sweden	4.2	9.6

Results are expressed as percent change.

Table 4. Productivity, unit labor cost, and price: Iron and steel industry (1975–1980)

		Unit labor cost		
	Productivity	Local currency	U.S. dollars	Producer price
Canada	1.9	10.2	7.2	10.1
France	7.8	4.6	4.9	7.6
Fed. Rep. of Germany	4.9	2.2	8.6	1.4
Japan	8.2	−1.3	4.3	6.3
Sweden	2.1	9.3	8.9	6.9
United Kingdom	−2.2	13.6	19.8	12.9
United States	0.9	10.3	10.3	8.7

Results are expressed as percent change.

to the poor showing by the United Kingdom.

A profit margin estimate is needed to translate these figures into final prices charged (all in U.S. dollar units) that would show the ultimate degree of competitiveness.

There are two gaps in all these tables. They do not cover many smaller countries that are important in the world trade system, particularly some fast-growing developing countries that play important roles in world export markets for manufactured goods. Second, these tabulations are mainly for large aggregates, the total GDP or output of the manufacturing sector.

Very careful data preparation must be undertaken to construct these data for developing countries. Both domestic sources and the statistical offices of the large international organizations could be used to fill the first gap. These data are available; it is only a matter of their being properly researched.

As for the specific industry analyses, a number of them have been estimated on the basis of production and employment data in some individual industries. Using Office of Economic Cooperation and Development data on indexes of production in individual industries, corresponding data on employment, and U.S. Department of Labor data on wage rates, we are able to construct series of growth rates of productivity and unit labor costs. Accompanying series for producer price indexes can also be prepared. This gives us a ready reference for looking at key industries across countries during recent history. The period 1975–1980 was chosen for reasons of commonality. Tables 4–9 show these comparative statistics on competitiveness for selected countries, chosen on the basis of availability, and some key industrial sectors—areas of maturity, cyclicality, and potential growth.

In this period, the relatively strong growth performance of Japan stands out and contributes so much from the side of productivity that exchange appreciation of the yen against the dollar does not wipe out the gains when unit labor cost is computed in U.S. dollar units. Both wage and price changes were also re-

Table 5. Productivity, unit labor cost, and price: Motor vehicle industry (1975–1980)

		Unit labor cost		
	Productivity	Local currency	U.S. dollars	Producer price
Canada	−2.1	14.3	10.9	9.0
France	3.1	10.7	11.0	—
Fed. Rep. of Germany	0.1	7.8	14.5	3.7
Japan	10.5	2.2	3.3	0.3
United Kingdom	−1.3	12.7	13.7	15.7
United States	2.3	9.0	9.0	7.6

Results are expressed as percent change.

Table 6. Productivity, unit labor cost, and price: Electrical machinery and electronics industry (1975–1980)

	Productivity	Unit labor cost: Local currency	Unit labor cost: U.S. dollars	Producer price
Canada	3.3	6.8	3.8	7.2
France	5.5	9.2	9.6	—
Fed. Rep. of Germany	5.0	3.0	9.5	2.0
Japan	14.1	−6.7	−1.5	0.4
Netherlands	7.8	1.5	6.5	1.6
Sweden	0.6	11.5	11.1	8.3
United Kingdom	1.8	19.9	21.0	13.4
United States	4.0	5.0	5.0	7.5

Results are expressed as percent change.

strained in Japan in comparison with other countries. On the negative side, the United Kingdom performed relatively poorly on both a productivity and competitiveness standard. The United States is neither the worst nor the best in these sectors, but such comparisons indicate that, if a cyclical recovery in productivity growth could be attained with wage and price restraint, the United States could be fully competitive in foreign trade markets.

SOME BILATERAL COMPARISONS

A comprehensive analysis using estimates of parametric production functions has not been made for individual industries in several countries nor even for manufacturing as a whole across a wide spectrum of countries. This could be done, and undoubtedly will, in future research, but there are some revealing studies of productivity comparisons of pairs of countries. Let us first consider Japan and the United States.

In a carefully documented study, Grossman and Sadler (9) have estimated output per worker hour for both Japan and the United States (Table 10). They also have estimates of total factor productivity. Their findings are of particular interest because they are estimated at a detailed industry level of disaggregation. In these findings, values of output were converted to 1975 dollars by using the Kravis ratios of purchasing power parity.

The results of Grossman and Sadler show an increase from \$8.27 to \$9.27 per hour for total private domestic business in the United States between 1970 and 1980. The corresponding gain for Japan was from \$3.59 to \$6.01. The United States has a much higher productivity level, but the gain over the decade was far greater in percentage terms for Japan. The same statistical pattern prevails across most industry groups, but the American agricultural performance remains impressive. In electrical machinery and primary metals, the Japanese gains and levels by 1980 are outstanding.

Table 7. Productivity, unit labor cost, and price: Chemicals industry (1975–1980)

	Productivity	Unit labor cost: Local currency	Unit labor cost: U.S. dollars	Producer price
Canada	3.2	6.7	3.8	10.5
France	4.8	10.0	10.3	9.5
Fed. Rep. of Germany	3.5	3.3	10.4	2.9
Japan	9.7	−1.0	4.6	9.3
Netherlands	6.9	0.8	5.7	—
Sweden	0.7	11.8	11.4	11.8
Switzerland	6.9	−3.0	5.8	−0.6
United Kingdom	2.6	20.5	21.6	16.3
United States	4.4	5.3	5.3	9.4

Results are expressed as percent change.

Table 8. Productivity, unit labor cost, and price: Textile industry (1975–1980)

	Productivity	Unit labor cost: Local currency	Unit labor cost: U.S. dollars	Producer price
Canada	3.6	7.0	4.0	9.0
Denmark	3.4	7.3	7.7	6.8
France	3.2	10.6	10.9	3.4
Fed. Rep. of Germany	3.6	3.7	10.2	2.6
Japan	4.2	4.1	9.9	4.2
Netherlands	7.9	−0.3	4.6	3.9
Sweden	0.3	12.4	11.9	8.6
Switzerland	5.8	−0.8	6.9	0.5
United Kingdom	−0.1	15.7	16.7	12.9
United States	3.0	6.1	6.1	5.9

Results are expressed as percent change.

From CES production functions with four factor inputs (*KLEM*), Kumasaka† has estimated total factor and labor productivity growth in manufacturing (Table 11). For Japan, a nested CES function was used, while, for the United States, a split level CES function with K and E at one level and L and M at another was used. Kumasaka finds that the labor productivity slowdown in Japan was associated mainly with decline in factor intensity, especially capital and materials, while the slowdown in the United States was accounted for mainly by a drop in energy and material intensity, with some overall drop in total factor productivity.

In earlier research at the University of Pennsylvania, Tange (11) estimated generalized Cobb–Douglas functions for Japan and the United States by similar industrial classifications. Her function was

$$X_{it} = A_i L_{it}{}^{\alpha_i} K_{it}{}^{\beta_i} \left(\prod_{j=1}^{n} X_{ji}{}^{\gamma_{ji}} \right) \exp(\lambda_{it}) e_{it}.$$

The γ_{ji} were estimated directly from input–output tables and include both energy and materials as intermediate inputs, and the estimation period was 1957–1974 (Table 12).

† Kumasaka, Y. (1983) Doctoral dissertation research, Univ. of Pennsylvania.

Table 9. Productivity, unit labor cost, and price: Paper and allied products (1975–1980)

	Productivity	Unit labor cost: Local currency	Unit labor cost: U.S. dollars	Producer price
Canada	3.5	7.1	4.2	9.2
France	6.1	7.7	8.1	5.8
Fed. Rep. of Germany	5.5	2.6	9.0	2.9
Japan	5.9	0.2	5.8	6.1
Netherlands	5.5	1.7	6.7	—
Sweden	3.0	9.8	9.3	7.1
United Kingdom	2.5	10.7	20.9	13.5
United States	2.6	7.4	7.4	7.9

Results are expressed as percent change.

Table 10. Levels of output per hour worked in the United States and in Japan (1970–1980)

	United States				Japan			
Industry segment	1970	1973	1974	1980	1970	1973	1974	1980
Private domestic business	8.27	9.06	8.28	9.27	3.59	4.64	4.73	6.01
Agriculture	6.17	6.24	6.32	7.21	1.37	2.05	2.11	2.38
Nonfarm nonmanufacturing	8.64	9.19	8.10	9.07	4.15	5.00	5.04	5.68
Mining	27.58	27.05	25.22	19.26	5.07	7.96	7.10	11.67
Construction	9.45	9.36	8.35	7.43	3.85	4.25	4.06	4.13
Transportation and communication	9.29	10.48	10.83	13.13	3.86	4.29	4.74	5.66
Electricity, gas, and water	21.98	24.40	23.32	25.38	14.01	14.09	15.05	19.74
Trade	6.88	7.70	7.55	7.92	2.88	3.90	3.98	4.53
Finance and insurance	8.21	8.32	8.45	8.20	6.69	10.32	9.03	12.03
Business services	6.79	7.10	5.04	6.70	3.39	3.60	3.60	3.60
Manufacturing	7.92	9.30	9.09	10.17	3.91	5.12	5.31	8.00
Food and tobacco	9.51	12.04	11.43	13.35	3.81	5.61	6.03	7.07
Textiles	5.11	5.60	5.33	7.10	1.58	1.82	2.47	2.93
Pulp and paper	8.28	10.75	11.02	11.16	5.11	7.13	6.83	9.20
Chemicals	10.26	13.20	12.67	14.91	6.54	10.48	10.63	17.77
Primary metals	11.51	13.47	13.52	12.01	8.61	13.20	12.12	21.43
Fabricated metals	8.53	9.27	8.60	10.05	3.32	4.85	4.16	4.75
Machinery (excluding electrical)	8.54	9.34	9.18	10.04	4.03	4.59	4.78	7.98
Electrical machinery	6.90	8.01	7.54	10.22	2.78	5.03	5.68	13.32
Transportation equipment	8.47	10.91	10.62	10.90	5.19	5.89	6.82	10.30
Other manufacturing*	6.56	7.47	7.45	8.23	3.83	4.26	4.16	5.13
Service producing†	8.16	8.80	7.75	8.98	4.20	5.16	5.26	6.03
Goods producing‡	8.37	9.33	9.02	9.68	3.14	4.22	4.29	5.99

Results are expressed in constant 1975 U.S. dollars per hr. Japan real output in 1975 yen was converted to 1975 U.S. dollars by using the 1970 purchasing power parity (PPP) as given by Kravis (5) extrapolated to 1975; PPP in 1975 was 272.5 yen per U.S. dollar (see ref. 10). Source: see ref. 9.

* Includes apparel; lumber; furniture; printing and publishing; petroleum; stone; clay, stone, and glass; leather; instruments; and miscellaneous manufacturing.

† Includes nonfarm nonmanufacturing exclusive of mining and construction.

‡ Includes manufacturing, agriculture, mining, and construction.

Some of the estimates do not include data for 1974, and satisfactory estimates of the production function for manufactured food products were not obtained for the United States, so this sector is not included in the comparison. The main point, however, is clear. The rate of technical progress, identified as total factor productivity, is uniformly larger in this tabulation across industrial groups for Japan. A use to which these estimates of the production functions were put was to develop indexes of relative cost efficiency, which were then correlated with relative export performance. The evidence is strongly indicative that cost efficiency promoted superior export performance.

INTERNATIONAL POLICY COMPARISONS

By and large, it will be agreed among countries that productivity is a good thing, that its growth should be encouraged. It is not without its drawbacks and problems, but there are hardly any countries that will deliberately try to discourage productivity advances. Some may try to moderate its influence. But there will be wide differences among countries in the choice of policies to enhance productivity growth. At one extreme, we may find active *industrial policies* that place productivity growth at the head of the list of economic priorities. It is often felt that Japanese economic policy of the 1950s and 1960s was a case of intensive and fruitful use of industrial policy to encourage productivity growth and a high state of competitiveness (12).

In their case it was a problem of establishing a consensus, involving both the public and corporate sectors, with the cooperation of labor, to delineate the potential winning sectors,

Table 11. Productivity growth in the United States and in Japan (1966–1980)

	Growth, %	
	1966–1973	1974–1980
Total factor productivity		
Japan	0.74	0.79
United States	0.35	0.18
Labor productivity		
Japan	8.90	4.69
United States	2.30	1.11

Table 12. Estimates of total factor productivity in Japan and in the United States: Cobb–Douglas specification (1957–1974)

	Estimate, %	
	Japan	United States
Textile mill products	2.5	1.6
Paper and allied products	2.6	1.6
Chemicals and allied products	3.0	2.7
Primary metals	1.5	—
Fabricated metals	1.9	0.6
Nonelectrical machinery	3.2	1.4
Electrical machinery	5.5	2.6
Transportation equipment	5.5	1.6

to favor them with fiscal and other incentives, and to develop them to a state at which they show the high productivity growth rates that we find in the tables presented here. It was a dedicated policy and apparently successful, as far as productivity growth is concerned.

It is sometimes felt that "le Plan" in France during the 1960s accomplished similar achievements. On the other hand, there are abundant examples of failed industrial policies in which "losers" got more support than "winners" and, as a consequence, productivity gains suffered. The United Kingdom of the 1950s, 1960s, and 1970s provides examples, as do Sweden and some other countries.

A popular view is that public authorities should simply make the overall economic environment attractive and conducive to capital formation, allowing the conventional market-oriented process to do the picking of potential winners.

Appropriate policies for establishing an environment in which productivity might thrive are plentiful support for research and development, both civilian and military, support for basic research, tax policies that favor investment incentives (accelerated depreciation, investment tax credits, research and development tax credits), easy credit policies, export financing, and similar devices.

This is the prevailing view in the United States, and some of these proposals will find expression in future policy packages. Productivity now shows some signs of reviving on its own cyclical path and, with an encouraging economic environment, is likely to make U.S. productivity grow at a much better rate than in the latter part of the 1970s.

1. *Oxford English Dictionary* (1971) (Oxford Univ. Press, New York).
2. Jevons, W. S. (1878) *Primer of Political Economy* (Macmillan, London), p. 54.
3. Fabricant, S. (1968) in *International Encyclopedia of the Social Sciences*, ed. Sills, D. L. (Macmillan, New York), p. 523.
4. Arrow, K. J. (1974) in *Nations and Households in Economic Growth*, eds. David, P. A. & Reder, M. W. (Academic, New York), pp. 3–19.
5. Kravis, I. B., Heston, A. & Summers, R. (1982) *World Product and Income, International Comparisons of Real Gross Product* [Johns Hopkins Univ. Press (for the World Bank), Baltimore].
6. Capdevielle, P., Alvarez, D. & Cooper, B. (1982) *Mon. Labor Rev.* **105** (12), 3–14.
7. Giersch, H. & Wolter, F. (1982) *On the Recent Slowdown in Productivity Growth in Advanced Economies*, Kiel Working Paper No. 148 (Institut für Weltwrischaft an der Universität Kiel, Kiel, Federal Republic of Germany).
8. Lindbeck, A. (1983) *Econ. J.* **93**, 13–34.
9. Grossman, E. S. & Sadler, G. S. (1982) *Comparative Productivity Dynamics: Japan and the United States* (American Productivity Center, Houston, TX).
10. Summers, R., Kravis, I. & Heston, A. (1980) *Rev. Income Wealth* **26** (1), 19–66.
11. Tange, T. (1979) Dissertation (Univ. of Pennsylvania).
12. Shinohara, M. (1982) *Industrial Growth, Trade, and Dynamic Patterns in the Japanese Economy* (Univ. of Tokyo Press, Tokyo).