Multifactor productivity in manufacturing industries

Multifactor productivity growth improved somewhat in manufacturing during the 1984–88 period, however, slow growth persists in the aggregate business sector

William Gullickson

According to newly released multifactor productivity data for the 1984–88 period, the slow growth prevalent throughout the U.S. economy over the 1974–82 period has improved substantially in manufacturing.[1] For many broad manufacturing industry groups, productivity growth trends since 1979 are comparable to those from 1949–73, when productivity growth was faster. However, slow growth persists in the more aggregate business sector.

Certain trends relating to productivity became apparent in the 1970's, especially after the Arab oil embargo in 1974 and the recession that followed. During the energy crunch, fuel prices rose almost 150 percent in a 4-year period, 1973–77 (after energy prices had actually fallen throughout the 1960's). Researchers began to suspect that energy price movements of this magnitude could affect the use of other inputs—especially investment in capital goods, in turn, thought to be an important contributor to labor productivity growth. The situation was essentially similar in the case of nonfuel raw materials, a category of input much larger than fuels. Manufacturing materials prices rose by 5 percent over the 1949–69 period, and by more than 300 percent during the 1970's. Lastly, increases in the use of business services came to light. Business services include computer services and equipment leasing, among other important services, all of which could have an important role in production and employment.

William Gullickson is an economist in the Division of Productivity Research, Office of Productivity and Technology, Bureau of Labor Statistics.

These trends spurred the Bureau of Labor Statistics to enhance the level of industry detail in the multifactor productivity program so that growth could be closely analyzed, rather than viewed in the aggregate. At the same time, the Bureau expanded the scope of these measures to include raw materials and business service inputs, allowing assessment of economies in those inputs along with labor and capital. Thus, multifactor productivity measures for manufacturing industries compare output to five categories of input—capital, labor, energy, nonenergy materials, and business services (collectively identified as KLEMS). This allows study of the changing relationships between various inputs in production, between input and output price, as well as the growth of multifactor productivity among industries.

This article reviews some of the Bureau's 1984–88 measures of multifactor productivity for manufacturing industries and updates the data featured in an earlier *Review* article covering the 1949–83 period.[2] In particular, this article discusses the differences in industry productivity growth rates and the extent of the recovery in growth. The last section examines the contribution of manufacturing to productivity growth in the private business sector. A simple relation between sector and aggregate productivity measures allows examination of the contribution of the manufacturing industries to productivity growth for all U.S. private business.

Measurement framework and data

Most of the data underlying the KLEMS measures are based on published results of large ongoing surveys, namely the Census of Manufactures and

Annual Survey of Manufactures from the Department of Commerce and the Current Employment Statistics program from BLS.[3] The census data include the values of shipments (and inventory change) as well as cost of materials and fuels; the Current Employment Statistics survey provides numerous series on employment, hours, and earnings. Both the census and Current Employment Statistics surveys provide establishment data which pertain to plants rather than to corporate or other units. Extensive use is made of tabulations of census data prepared by the Bureau of Economic Analysis, U.S. Department of Commerce.

Two data series not derived directly from the census and Current Employment Statistics data are the capital and business service inputs. Capital input is defined as the flow of services from physical assets, such as equipment, structures, inventories, and land. Service flows are derived from capital stock measures. For depreciable assets (equipment and structures), these stocks are measured from historical data on real investments by assuming that services decline gradually, early in an investment cohort's life, and declines more quickly later.[4]

Stocks of assets of up to 25 types of capital for each manufacturing industry are combined using weights based on implicit rental price estimates. The capital rental price formula consists of a rate of return, plus a rate of depreciation, less a rate of revaluation, adjusted for the effects of tax laws. The revaluation rate was computed as a 3-year moving average of the annual change in the deflator for new investment. Essentially, rental prices are used to apportion property income among the assets earning such income. These property income shares are used as weights for corresponding stocks in the aggregation of stocks.[5]

Aggregation of capital inputs, as well as output and other nonlabor inputs, is done using the Tornqvist method. This procedure computes a growth rate of an aggregate between any two periods which is a weighted average of growth rates of its components, with weights given by the average share of each component in the value of the aggregate for the two periods.[6] (The use of weights based on value is consistent with the basic economic assumption that production processes can be modified, and the level of each input adjusted until the marginal product of an increment to any input is equal to its price.) Growth rates in the aggregate are then chained into an index; prices are obtained as the value of the aggregate divided by the quantity index.

Business service inputs to the manufacturing sector include: communications (telephone and telegraph services); finance and insurance; real estate rental; hotel services; repair services; business services, including equipment rental, engineering and technical services, and advertising; vehicle repair; medical and educational services; and purchases from government enterprises. Estimates of business service inputs are based on the input-output tables of the U.S. economy compiled by the Bureau of Economic Analysis. Exhibit 1 summarizes data sources and methods used to compare

Table 1. **Multifactor productivity growth in U.S. manufacturing industries, selected periods**

[Compound annual average growth rates]

Industry	1949–88	1949–73	1973–88	1949–79	1979–88
Total manufacturing	1.3	1.6	0.9	1.2	1.6
Nondurable goods	1.0	1.4	.4	1.1	0.9
Food and kindred products	0.6	0.8	.3	0.6	.7
Tobacco manufactures	0	1.3	–2.1	1.0	-3.1
Textile mill products	1.6	1.8	1.3	1.8	1.0
Apparel and related products	1.1	1.1	1.2	1.1	1.4
Paper and allied products	1.0	1.2	.6	.8	1.5
Printing and publishing	3	.7	–.3	.5	–.3
Chemicals and allied products	1.8	2.5	.7	1.8	1.6
Petroleum products	4	.8	–.2	.6	–.1
Rubber and miscellaneous plastics products	1.0	1.0	.9	.6	2.1
Leather and leather products	.4	.4	.3	.4	.4
Durable goods	1.3	1.4	1.2	1.1	2.0
Lumber and wood products	1.6	2.0	1.0	1.7	1.6
Furniture and fixtures	.6	.8	.4	.8	.2
Stone, clay, and glass products	.7	1.0	.1	.6	.7
Primary metal industries	–.2	.1	–.7	–.5	.5
Fabricated metal products	.6	.6	.5	.4	1.0
Machinery, except electrical	1.7	1.0	2.9	1.0	4.3
Electrical and electronic equipment	2.1	2.1	2.0	2.0	2.1
Transportation equipment	1.0	1.2	.6	1.0	.9
Instruments and related products	1.4	1.7	.9	1.5	.9
Miscellaneous manufacturing	1.1	1.3	.7	.9	1.8

Exhibit 1. **Summary of sources and methods for the KLEMS data**

Category	Value or cost	Quantity	Price
Two-digit output	Census value of shipments, plus Bureau of Economic Analysis inventory change, less nonfactor costs (some indirect business tax, subsidies), less intrasector transaction	Current value of production (shipments plus inventory change less nonfactor costs) deflated using two-digit production deflator (Bureau of Economic Analysis) adjusted to reflect Tornqvist aggregation, from four-digit to two-digit, less real intrasector transaction (Tornqvist disaggregation)	Implicit
Two-digit real value of shipments	Census	Direct aggregate of four-digit real shipments, deflated by BLS producer prices	Implicit
Two-digit inventory change	Bureau of Economic Analysis	Implicit	Bureau of Economic Analysis
Composition adjustors	Census four-digit values of production	Implicit	Four-digit BLS Producer Price Indexes
Two-digit intrasector transactions	Input-output tables	Implicit	BLS Producer Price Indexes
Two-digit total input	Sum of input costs, adjusted to the value of production	Tornqvist aggregate of input and types	Implicit
Capital input	National Income and Products Accounts	Tornqvist aggregate of capital stocks	Implicit
Capital stock by asset type	Implicit	Perpetual inventory formula	Rental price
Labor input	National Income and Products Accounts	BLS-790 Current Employment Statistics	Implicit
Energy input	Census	Tornqvist aggregate of five fuel types	Implicit
Fuel types (benchmark years)	Census	Physical units (tons, for example)	Implicit
Fuel types (interim years)	Census	Implicit	BLS Producer Price Indexes
Nonenergy material input	Census cost of materials less intra-sector transactions and energy costs	Tornqvist disaggregation of real material input, intra-sector transactions, and energy inputs	Implicit
Material inputs	Census	Implicit	Bureau of Economic Analysis input price composites for two-digit industries adjusted to reflect Tornqvist aggregation
Intra-sector transactions	Input-output tables	Implicit	BLS Producer Price Indexes
Business service inputs	Input-output tables	Tornqvist aggregate of service types	Implicit
Service types	Input-output tables	Implicit	BLS Producer Price Indexes and Bureau of Economic Analysis prices

output to combined inputs from capital, labor, energy, nonenergy materials, and business services.

As exhibit 1 suggests, either quantity or price is based on an "explicit" data source, while the other is derived implicitly as the ratio of current value to the explicit component. Because there are, in most cases, many subcategories, the "explicit" component for the major category is (in all cases but labor) determined as a Tornqvist index of subcomponent quantity estimates. At the subcomponent level, the Census of Manufactures generally provides detail on the distribution of value. Capital asset detail is an exception.

Productivity growth

The data previously published covering the 1949–83 period indicated that the dramatic slowdown in productivity growth seen in other productivity measures was also evident in the two-digit manufacturing industry indexes of multifactor productivity. Using 1973 to delineate early and late periods for comparison, the previous study revealed that most industries experienced some degree of slowdown. In total manufacturing, the growth rate dropped from 1.5 percent to 0.3 percent per year; among the 20 industries studied, growth slowed by some degree in all but three—textile mill products, machinery except electrical, and electrical and electronic equipment. In most other industries, growth slowed substantially, by at least 0.3 percentage points.

The picture presented by the updated data is somewhat improved. (See table 1.) A comparison of the two periods shows that multifactor productivity in manufacturing as a whole increased 1.6 percent annually in the 1949–73 period, and 0.9 percent annually over the 1973–88 period. In nondurable industries, average annual growth after 1973 was 0.4 percent per year, compared with 1.4 percent before 1973; and in durable goods, 1.2 percent in the recent period, compared with 1.5 in the early period.

Extension of the data to 1988 allows computation of average growth rates beginning at the peak of the 1979 business cycle, and these averages might be more representative of current conditions. (See table 1.) The data suggest that growth of manufacturing productivity has resumed the pace of the early postwar period, notwithstanding the dismal performance of the late 1970's. For manufacturing as a whole, the average annual growth after 1979 in multifactor productivity was 1.6 percent per year, identical to the 1949–73 rate.

Multifactor productivity growth varies substantially across industries, both in terms of total

Chart 1. **Output, input, and multifactor productivity in U.S. manufacturing industries, 1973–88**

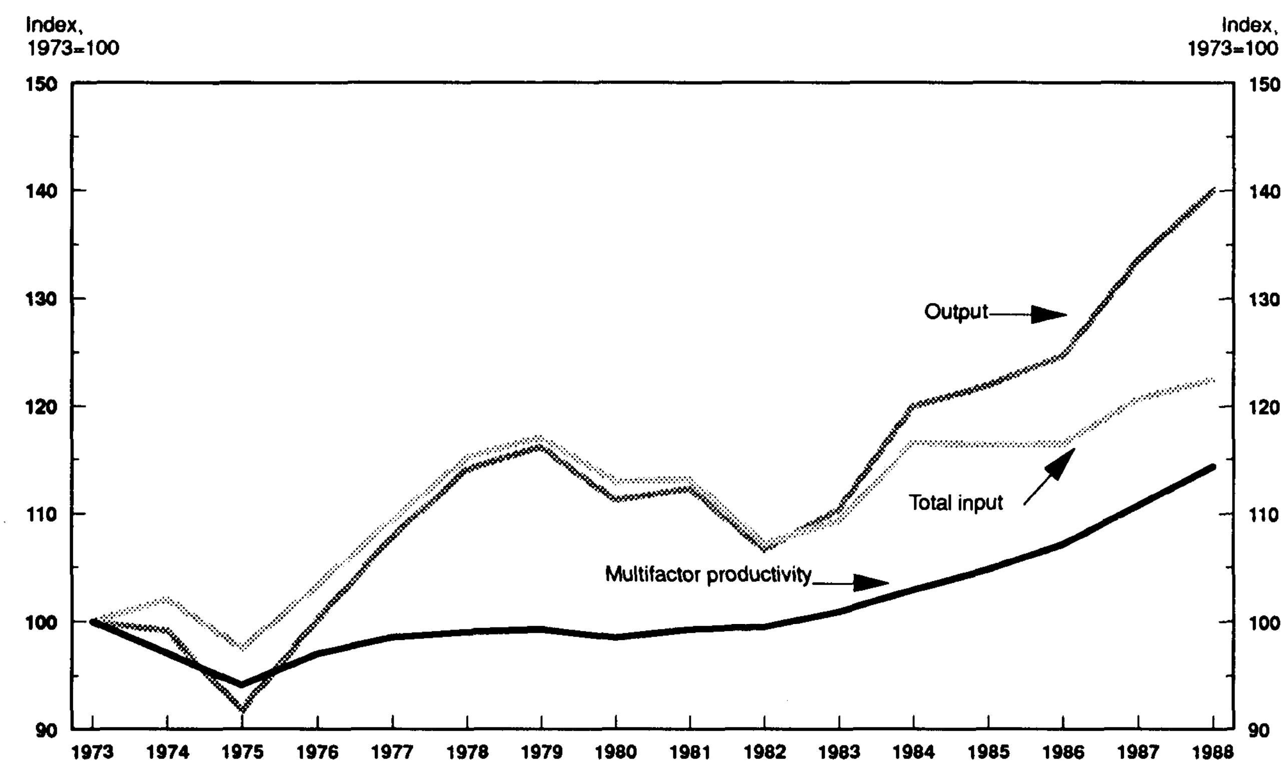

Table 2. **Input, output, and multifactor productivity growth, selected periods**

[Compound average annual growth rates]

Industry	Capital	Labor	Energy, nonenergy materials, and services	All inputs	Multifactor productivity	Output
Total manufacturing						
1949–86	3.8	0.7	3.0	2.1	1.2	3.3
1986–88	1.1	2.0	3.6	2.6	3.4	6.0
Nondurable goods						
1949–86	3.0	.3	2.4	1.8	1.0	2.9
1986–88	0.6	2.0	4.7	3.3	1.1	4.4
Food and kindred products						
1949–86	1.2	–.4	2.2	1.6	.6	2.3
1986–88	.4	.8	4.3	3.3	0	3.2
Tobacco manufactures						
1949–86	1.3	–1.8	.6	.3	.3	0.5
1986–88	–.5	.6	16.5	4.0	–4.7	–.8
Textile mill products						
1949–86	.7	–1.2	3.5	1.2	1.7	2.9
1986–88	–.8	2.1	7.7	4.7	0	4.7
Apparel and related products						
1949–86	3.1	–.2	1.7	1.0	1.1	2.1
1986–88	–.1	.3	3.4	1.9	2.3	4.3
Paper and allied products						
1949–86	3.7	1.0	3.8	2.8	.9	3.7
1986–88	1.9	2.1	2.3	2.2	1.7	3.9
Printing and publishing						
1949–86	4.1	1.7	4.5	3.1	.3	3.5
1986–88	4.4	4.1	6.9	5.4	.2	5.6
Chemicals and allied products						
1949–86	3.8	1.3	4.0	3.0	1.7	4.8
1986–88	–.5	2.6	7.4	4.4	3.2	7.8
Petroleum products						
1949–86	3.1	–.6	3.0	2.6	.4	3.0
1986–88	–2.2	–1.6	2.1	1.5	.3	1.8
Rubber and miscellaneous plastics products						
1949–86	5.0	2.9	4.7	4.1	.9	5.1
1986–88	.5	3.1	8.0	5.7	1.5	7.3
Leather and leather products						
1949–86	.6	–2.5	–.1	–1.2	.2	–1.0
1986–88	–2.7	.2	3.4	1.7	3.5	5.3
Durable goods						
1949–86	4.5	1.1	3.9	2.5	1.2	3.7
1986–88	1.6	1.9	3.7	2.6	4.9	7.6
Lumber and wood products						
1949–86	2.5	–.3	1.8	1.1	1.5	2.5
1986–88	–.5	4.8	1.6	2.4	5.2	7.7
Furniture and fixtures						
1949–86	3.3	1.3	3.2	2.5	.7	3.1
1986–88	4.0	1.8	7.6	5.3	.3	5.6
Stone, clay, and glass products						
1949–86	3.1	.4	2.8	1.8	.6	2.5
1986–88	–.9	1.5	8.0	4.3	1.2	6.0
Primary metals						
1949–86	2.9	–.9	2.1	1.2	–.4	.8
1986–88	–2.7	4.0	8.0	5.4	3.3	8.8
Fabricated metal products						
1949–86	3.9	1.1	2.6	2.2	.4	2.6
1986–88	.8	1.2	1.7	1.4	3.4	4.8
Machinery, except electrical						
1949–86	4.9	1.5	4.1	3.1	1.4	4.5
1986–88	2.6	2.2	13.6	7.8	7.8	16.2
Electrical and electronic equipment						
1949–86	6.8	2.5	4.0	3.6	1.9	5.6
1986–88	4.7	–.6	3.8	2.0	4.4	6.6
Transportation equipment						
1949–86	4.8	1.4	3.5	2.8	.9	3.7
1986–88	2.3	2.2	2.8	3.3	2.8	6.6
Instruments and related products						
1949–86	5.7	2.6	6.0	4.5	1.3	5.8
1986–88	4.8	3.5	4.3	4.0	2.8	6.9
Miscellaneous manufacturing						
1949–86	3.2	0	2.1	1.4	.9	2.3
1986–88	–.1	2.9	7.3	4.6	4.0	8.8

postwar growth and pattern of growth through subperiods. At the high end of the growth spectrum for the entire 1949–88 period are electrical and electronic equipment (2.1 percent per year); machinery, except electrical (1.7 percent); chemicals and allied products (1.8 percent); lumber and wood products (1.6 percent); and textile mills (1.6 percent). At the other extreme were primary metals with an annual decline of 0.2, and tobacco manufactures with no growth, on average.

Since 1979, the industries leading in productivity growth have been machinery, except electrical (4.3 percent per year); electrical and electronic equipment (2.1); rubber and miscellaneous plastics products (2.1); lumber and wood products (1.6); and chemicals (1.6). For the most part, the industries in which productivity grew fastest during the early period did not continue their fast pace into the later period. (Using the 1949–79 and 1979–88 time periods, only lumber and wood products; chemicals and allied products; machinery, except electrical; and electrical and electronic products were in the top third during both periods.) Multifactor productivity in rubber and miscellaneous, plastics and machinery, except electrical (which includes computers), grew much faster in the 1979–88 period than in the earlier years; multifactor productivity in instruments and related products grew fastest in the early period.

It is interesting to note the similarities of growth rates in the 1949–73 and 1979–88 periods for total manufacturing. This comparison disregards the 1973–79 years, which encompassed the most severe recession in the postwar period (in 1975), the energy crises in the mid-1970's, and a rate of inflation about twice that of years outside the period. Multifactor productivity growth rates for total manufacturing in the pre-1973 and post-1979 periods were identical at 1.6 percent per year; and in about a third of the industries, average growth rates in the late period equalled or exceeded those in the early period. It is thus tempting to consider the 1973–79 period an anomaly in analyzing the long-term growth of multifactor productivity.

Table 2, which shows the growth in inputs, in output, and in multifactor productivity between 1986 and 1988, sheds some light on the improvement in productivity growth over the last few years. Obviously, the years after 1986 were good ones, especially in durable manufacturing. The growth rate in durable goods output as a whole was more than twice the rate evidenced before 1986; there was a substantial improvement in output growth rate in all durable industries (led by machinery, except electrical, which includes computers). The acceleration of multifactor productivity growth coincided with the rapid growth in output which commenced around 1983. (See chart 1.)

Multifactor productivity represents the difference between the growth of output and the growth of a composite of all inputs and therefore represents the extent to which output may grow beyond the increased use of scarce inputs. It also represents the difference between output price change and the change in a composite price for all inputs—the "primal" relationship between output and inputs and its "dual," the relation between output and input prices result in the same multifactor productivity measure, by construction.[7] It is in this connection that productivity takes on a particular significance in the present, highly competitive manufacturing environment: productivity growth represents the means by which a competitive position may be enhanced in the absence of input price reductions; the means by which the effects of input price increases may be mitigated; or the means by which payments to labor and to the owners of capital may rise without increasing price.

Table 3 shows average movements in input prices, multifactor productivity, and output price in selected postwar periods. The importance of multifactor productivity growth in offsetting the effects of input price increases is suggested in this

Chart 2. **Contribution of manufacturing and nonmanufacturing industries to multifactor productivity in the business sector, 1949-88**

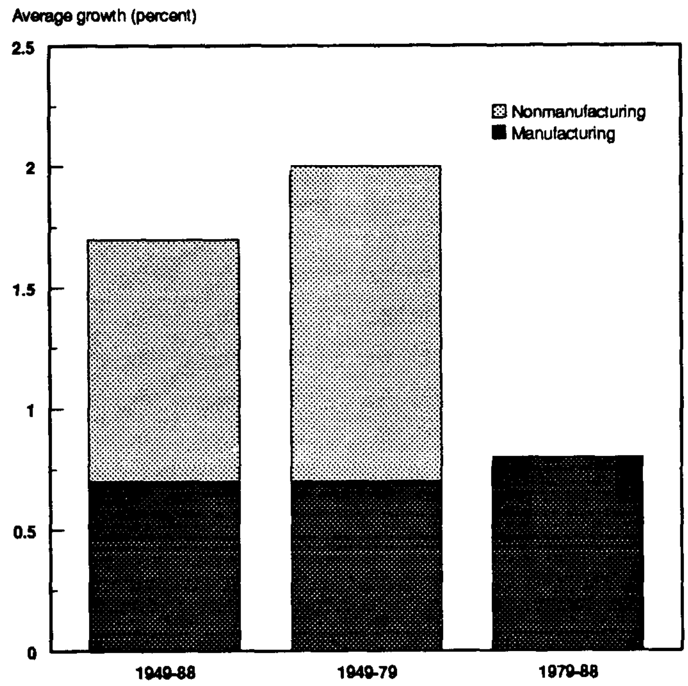

Table 3. **Growth rates of input prices, multifactor productivity, and output price in manufacturing industries, selected periods**

[Compound average annual growth rates]

SIC code	Industry	Capital	Labor	Energy	Non-energy materials	Services	All inputs	Output	Multi-factor productivity
20-39	Total manufacturing								
	1949-73	2.0	5.4	1.5	2.3	3.2	3.7	2.1	1.6
	1973-79	5.6	9.6	20.5	11.3	7.5	9.6	9.8	–.2
	1979-88	4.8	5.8	4.3	2.3	6.2	4.6	2.9	1.6
20-23, 26-31	Nondurable goods								
	1949-73	2.4	5.1	1.5	2.1	3.2	3.2	1.7	1.4
	1973-79	7.6	9.6	21.8	12.6	7.4	10.8	11.2	–.3
	1979-88	7.4	6.0	3.6	1.2	6.1	4.2	3.2	.9
20	Food and kindred products								
	1949-73	2.9	5.5	1.3	2.5	3.3	3.1	2.3	.8
	1973-79	9.1	9.8	20.0	5.8	7.6	6.9	7.4	–.4
	1979-88	9.6	5.8	4.8	1.7	6.1	3.4	2.7	.7
21	Tobacco manufactures								
	1949-73	5.7	7.1	.9	1.9	3.0	3.7	2.3	1.3
	1973-79	10.7	12.2	16.6	5.7	7.7	9.0	9.7	–.6
	1979-88	12.2	10.8	6.5	–10.1	6.1	7.0	10.5	–3.1
22	Textile mill products								
	1949-73	1.7	4.5	1.0	.2	3.4	2.3	.5	1.8
	1973-79	6.7	8.1	18.3	4.4	7.4	6.6	4.8	1.7
	1979-88	4.4	5.7	5.1	2.6	6.1	4.3	3.3	1.0
23	Apparel and related products								
	1949-73	0.9	4.1	.4	1.0	3.2	2.3	1.1	1.1
	1973-79	5.8	8.2	16.9	4.5	7.3	6.4	5.6	.8
	1979-88	8.4	5.4	6.3	3.1	6.2	4.8	3.3	1.4
26	Paper and allied products								
	1949-73	2.7	5.4	2.2	2.2	3.3	3.5	2.2	1.2
	1973-79	4.3	10.6	20.5	9.7	7.5	9.6	10.3	–.7
	1979-88	9.8	6.3	3.2	5.5	6.1	6.5	5.0	1.5
27	Printing and publishing								
	1949-73	2.5	4.6	–.6	2.0	3.0	3.4	2.6	.7
	1973-79	7.6	7.7	18.5	10.2	7.2	8.5	8.9	–.4
	1979-88	6.8	5.7	4.3	4.1	6.1	5.4	5.7	–.3
28	Chemicals and allied products								
	1949-73	2.4	5.6	1.7	1.5	3.1	3.2	.7	2.5
	1973-79	2.6	10.2	21.5	15.3	7.4	10.7	11.5	–.7
	1979-88	10.6	6.1	2.6	4.1	6.2	6.3	4.7	1.6
29	Petroleum products								
	1949-73	1.3	5.0	4.4	1.3	3.4	1.9	1.6	.8
	1973-79	20.7	13.8	29.5	27.9	7.5	25.2	23.5	–.3
	1979-88	–2.4	5.5	1.9	–1.9	6.2	–1.2	.4	–.1
30	Rubber and miscellaneous plastics products								
	1949-73	3.5	4.6	1.6	1.1	3.2	2.6	1.6	1.0
	1973-79	.8	7.8	18.1	11.9	7.4	9.4	10.4	–.9
	1979-88	5.8	5.7	5.1	5.7	6.2	5.8	3.6	2.1
31	Leather and leather products								
	1949-73	2.0	4.5	.2	1.1	3.2	2.9	2.5	.4
	1973–79	7.9	7.4	17.8	12.6	7.4	9.7	9.7	0
	1979–88	1.0	5.6	5.2	3.2	6.2	4.2	3.8	.4
24, 25, 32–39	Durable goods								
	1949 73	1.8	5.5	1.5	2.5	3.3	3.9	2.5	1.4
	1973–79	4.0	9.5	19.0	9.0	7.5	8.7	8.7	0
	1979–88	2.0	5.7	4.9	4.1	6.2	4.9	2.8	2.0
24	Lumber and wood products								
	1949–73	4.2	6.0	.4	5.3	3.6	5.3	3.2	2.0
	1973–79	5.4	9.1	17.7	10.8	7.8	9.2	9.0	0.2
	1979–88	5.3	4.5	4.7	.8	6.2	3.2	1.6	1.6
25	Furniture and fixtures								
	1949–73	1.1	4.6	.6	2.4	3.2	3.1	2.3	.8
	1973–79	10.2	8.2	16.9	8.6	7.5	8.6	7.9	.6
	1979–88	5.1	5.7	5.7	3.6	6.2	4.7	4.5	.2
32	Stone, clay, and glass products								
	1949–73	3.0	5.5	2.2	2.2	3.5	3.7	2.7	1.0
	1973–79	5.2	9.7	20.5	9.9	7.5	9.8	10.7	–.8
	1979–86	–.7	5.6	4.2	4.5	6.1	4.7	3.9	.7
33	Primary metal industries								
	1949–73	1.5	5.8	2.1	2.2	3.3	3.4	3.3	.1
	1973–79	7.5	10.9	19.3	9.1	7.7	9.9	12.7	–2.5
	1979–88	3.6	4.2	5.1	4.0	6.1	4.5	3.9	.5

Table 3. **Continued—Growth rates of input prices, multifactor productivity, and output price in manufacturing industries, selected periods**

[Compound average annual growth rates]

SIC code	Industry	Capital	Labor	Energy	Non-energy materials	Services	All inputs	Output	Multi-factor productivity
34	Fabricated metal products								
	1949–73	2.0	4.6	.4	3.1	3.3	3.5	2.9	0.6
	1973–79	9.1	9.3	18.3	11.5	7.4	10.4	10.8	–.3
	1979–88	5.2	5.0	4.8	3.8	6.2	4.5	3.5	1.0
35	Machinery, except electrical								
	1949–73	2.8	5.4	.9	2.8	3.3	3.9	2.9	1.0
	1973–79	4.4	9.5	17.5	8.6	7.2	8.5	7.4	1.0
	1979–88	–4.2	6.0	5.2	1.3	6.2	3.0	–1.2	4.3
36	Electrical and electronic equipment								
	1949–73	1.1	4.9	.6	2.8	3.2	3.6	1.5	2.1
	1973–79	2.8	9.2	18.5	9.3	7.4	8.6	6.5	1.9
	1979–88	.8	7.0	5.6	4.6	6.3	5.5	3.3	2.1
37	Transportation equipment								
	1949–73	.1	6.1	1.4	2.8	3.2	3.6	2.3	1.2
	1973–79	–4.8	9.6	18.7	10.9	7.7	9.0	8.8	.2
	1979–88	7.9	5.6	4.9	4.4	6.2	5.4	4.5	.9
38	Instruments and related products								
	1949–73	5.8	5.7	.9	2.2	3.1	4.2	2.5	1.7
	1973–79	1.1	8.3	17.2	8.6	7.4	7.5	6.6	.8
	1979–88	–3.6	7.1	5.5	3.8	6.2	4.8	3.8	.9
39	Miscellaneous manufacturing								
	1949–73	1.8	4.9	.9	2.1	3.1	3.2	1.9	1.3
	1973–79	4.1	7.9	17.9	9.7	7.3	8.4	9.4	–.9
	1979–88	10.0	5.5	3.7	4.5	6.2	5.7	3.8	1.8

table. Averages for three periods are shown, and special attention should be given to the contrasts between the early and late periods and the 1973–79 period. It was during the mid-1970's that the economy suffered a simultaneous increase in input price growth rates and a productivity slowdown which, together, had disastrous consequences for price growth.

In the pre–1973 period, multifactor productivity growth absorbed about 43 percent of the increase in input prices, and in the post–1979 period about 35 percent was offset, judging from the data for total manufacturing. In both periods, the output price increase was less than the increase in the composite price of inputs by 1.6 percentage points per year. In the 1973–79 period, there was no multifactor productivity growth to dampen the extraordinary input price growth. For 11 of the two-digit industries, output price actually grew faster than the prices of inputs—losses in production efficiency (negative productivity growth rates) reflecting the turmoil of this period.

Manufacturing and aggregate growth

The BLS productivity measures for large economic aggregates, such as the quarterly labor productivity and annual multifactor measures for the private business and the nonfarm sectors, have the virtue of showing trends in economic efficiency, technological change, and costs on a timely basis. The quarterly series is prepared within 6 weeks after the end of each quarter and the annual multifactor measures, within about 9 months of the end of each year.[8] One reason these measures can be computed so promptly is that they avoid the substantial complication of having to measure the transactions between producers within the economy. Both the output and the input measures underlying the aggregate productivity series exclude these transactions. Output is defined as deliveries to final users (households, investors, governments, and net exports), conveniently available from the U.S. National Income and Product Accounts; inputs include labor and, in the case of the annual multifactor series, the services of existing capital, but exclude items provided by industrial producers to each other. The aggregate measures allow the economic benefits of productivity to be seen in very broad, unambiguous terms.

Tracing the sources of productivity growth for the economy as a whole is of fundamental interest to economists, businessmen, policymakers, and labor leaders alike. One approach to such analysis is to relate the growth of productivity measured for the aggregate to industry productivity growth. This is one important application of the industry KLEMS productivity measures.

One relationship between aggregate productivity measures and industry measures based on *value-added* concepts has been in use for many years. As part of the National Income and Product Accounts, a set of industry (two-digit) deflated

Table 4. **Multifactor productivity growth rates in manufacturing and in all private business, 1949-88**

Year	Multifactor productivity change (percent)		Value of manufacturing production (billions of dollars)	Private business payments for capital and labor (billions of dollars)	Manufacturing		
	Private business[1]	Manufacturing[2]			Contribution to to private business multifactor productivity[3] (percent)	Payments for capital and labor (billions of dollars	Share of private business capital and labor costs (percent)
1950	4.6	5.3	$136.2	$227.2	3.2	$81.8	36.0
1951	4.7	.1	159.3	259.5	0	95.1	36.7
1952	4.6	1.6	166.8	269.7	1.0	100.3	37.2
1953	3.4	1.7	180.7	283.6	1.1	110.0	38.8
1954	1.2	–.1	171.7	282.2	–0.1	104.7	37.1
1955	1.8	2.8	190.8	310.0	1.7	118.5	38.2
1956	1.3	–1.4	199.4	329.5	–.8	124.6	37.8
1957	2.3	.7	208.0	344.6	.4	129.4	37.6
1958	3.0	–1.0	196.6	343.1	–.6	122.8	35.8
1959	2.0	4.9	216.1	374.6	2.8	140.3	37.5
1960	1.6	–.4	218.7	386.5	–.2	141.6	36.7
1961	2.6	1.7	220.8	395.9	1.0	142.2	35.9
1962	3.4	2.4	236.0	425.2	1.3	155.5	36.6
1963	2.5	3.2	245.8	447.6	1.8	164.9	36.8
1964	2.9	3.3	262.0	479.8	1.8	176.1	36.7
1965	2.5	2.8	286.3	522.1	1.5	193.7	37.1
1966	3.0	.7	317.4	569.5	4	213.5	37.5
1967	2.0	–1.1	335.2	597.5	–.6	219.7	36.8
1968	2.7	.9	360.3	649.9	.5	239.8	36.9
1969	.2	.9	382.0	701.2	.5	254.0	36.2
1970	.5	–1.6	383.7	725.4	–.8	248.1	34.2
1971	1.9	2.9	407.6	779.5	1.5	261.5	33.6
1972	1.7	4.1	458.0	863.9	2.2	291.8	33.8
1973	.8	3.5	531.7	979.0	1.9	328.3	33.5
1974	–1.5	–3.0	620.7	1051.7	–1.8	351.2	33.4
1975	.9	–3.0	642.5	1138.2	–1.7	363.0	31.9
1976	2.1	3.2	733.3	1278.1	1.8	418.4	32.8
1977	.9	1.5	836.7	1437.6	.9	475.4	33.1
1978	.6	.4	944.3	1631.3	.2	530.3	32.5
1979	–.8	.2	1,079.1	1818.2	.1	579.9	31.9
1980	–1.1	–.8	1,174.2	1955.5	–.5	602.9	30.8
1981	–.6	.9	1,296.6	2184.6	.5	665.7	30.5
1982	–.4	.5	1,264.9	2262.0	.3	656.0	29.0
1983	2.0	1.7	1,311.4	2420.6	.9	689.1	28.5
1984	1.3	1.8	1,448.6	2710.9	.9	771.5	28.4
1985	1.5	1.7	1,465.1	2894.1	.9	792.9	27.4
1986	2.4	2.3	1,444.1	3056.7	1.1	820.4	26.8
1987	.7	3.4	1,569.1	3263.6	1.6	886.3	27.0
1988	1.1	3.3	1,686.8	3541.3	1.6	957.3	27.0
	Annual average rate of change						
1949–88	1.7	1.3	.....	.....	.7	.....	35.4
1949–73	2.4	1.6	.....	.....	.9	.....	36.4
1973–79	.3	–.1	.....	.....	–.1	.....	31.1
1949–79	2.0	1.2	.....	.....	.7	.....	35.4
1979–88	.8	1.6	.....	.....	.8	.....	27.8

[1] Private business sector productivity is defined as real gross product for the sector per unit of combined capital and labor. For a further description of this measure, see text footnote 10. Note that the private business productivity figures used here have not been recomputed to reflect the recent (December 4, 1991) benchmark revisions to the National Income and Product Accounts.

[2] Manufacturing productivity is real gross output, excluding intrasector transactions, per unit of combined capital, labor, energy and nonenergy materials, and business service inputs.

[3] The manufacturing contribution to private business multifactor productivity change is the percentage-point contribution of manufacturing to private business multifactor productivity growth. This contribution is computed as the growth rate of manufacturing multifactor productivity multiplied by the ratio of the manufacturing value of production to private business payments for capital and labor (which is equal to business sector deliveries to final consumers).

value-added output measures, which sum to real GNP, is available. If industry productivity measures are based on these value-added output measures (that is, if multifactor productivity for industries is defined as real value-added per unit of capital and labor combined), the relation between industry and aggregate measures is straightforward: because both the numerator and denominator of the aggregate measure are sums of the industry detail, aggregate productivity is the weighted average of industry productivity measures, with weights based on the denominators of the industry measures, that is, industry inputs.[9]

Multifactor productivity measures for individual manufacturing industries defined as gross output per combined unit of all inputs *including intermediates*, such as the KLEMS measures, may also be related to multifactor productivity measures for the economy as a whole, although the latter consider only primary inputs (capital and labor). A widely accepted framework to attribute aggregate productivity change to industries was proposed by Evsey Domar. (See the appendix.) Here, the weights used are ratios of each industry's value of production to the value of aggregate output, both in current dollars. The rate of aggregate productivity growth is thus the weighted *sum* of sector productivity growth rates, where weights are ratios of each industry's value of production to total (economy-wide) production (deliveries to final demand).

Table 4 shows annual change in multifactor productivity for all private business, for manufacturing, and the relationship between them. The business sector multifactor productivity is defined as the real gross product of the private business sector per unit of combined capital and labor;[10] manufacturing multifactor productivity is real gross output per unit of combined capital, labor, energy, nonenergy materials, and business service inputs. The percentage-point contribution of manufacturing to aggregate productivity change, as explained in the appendix, is obtained as the manufacturing KLEMS productivity growth rate multiplied by the ratio of the manufacturing value of production to private business gross product (payments to capital and labor by the business sector). Also shown in table 4 is manufacturing gross product (the cost of labor and capital services), and the proportion of private business gross product originating in manufacturing.

The averages indicate that in the early part of the postwar period, the contribution of manufacturing industries to aggregate productivity growth was roughly commensurate with the size of manufacturing, measured by gross product originating. During the early period, 1949–73, about a third (0.9 percentage points) of the average annual growth in private business multifactor productivity (2.4 percent per year) was accounted for by manufacturing; the portion of private business gross product originating in manufacturing was also about a third.

During the 1979–88 period, the situation was quite different; the average annual growth in private business multifactor productivity declined to only 0.8 percent per year. The contribution to this growth rate from manufacturing was also 0.8 percentage points. Thus, by this accounting, all of the growth in private business multifactor productivity is attributable to manufacturing, although the manufacturing share of gross product has declined to 28 percent. This comparison suggests severe declines in the contribution to private business productivity of nonmanufacturing industries. (See chart 2.)

The contribution of individual industries to aggregate productivity (and to subaggregate productivity) growth can be computed in the same way. The attribution of total manufacturing and private business sector multifactor productivity growth is shown in table 5 (only industries whose annual contribution in any period rounds to at least 0.1 are shown.) The large contribution of machinery, except electrical demonstrates the impact of price and quantity data for computers in U.S. economic statistics: In the 1979–88 decade, fully one-third of private business multifactor productivity growth is attributable to the advances implicit in the data for this one manufacturing industry.[11] □

Table 5. **Selected industry contributions to private business multifactor productivity growth, selected periods**

[Average annual point contribution to growth]

Sector or industry	1949–88	1949–79	1979–88
Private business	1.7	2.0	0.8
Total manufacturing	74	.72	.79
Industry			
Nondurable goods industries	31	.33	.24
Food and kindred products	.07	.07	.07
Chemicals and allied products	.09	.10	.09
Rubber and miscellaneous plastics products	.02	.01	.05
Other nondurable goods industries	.13	.15	.03
Durable goods industries	.43	.39	.56
Machinery, except electrical	.12	.07	.26
Electrical and electronic equipment	.11	.11	.11
Transportation equipment	.11	.12	.08
Other durable goods industries	.09	.09	.11

Footnotes

[1] All data used in this study are for two-digit manufacturing industries from the *Standard Industrial Classification Manual*, 1972 Edition (Washington, DC, Office of Management and Budget).

[2] See William Gullickson and Michael J. Harper, "Multifactor productivity in U.S. Manufacturing, 1949–83," *Monthly Labor Review*, October 1987, pp. 18–28.

[3] Because the data sources and methodology underlying the KLEMS measures have been discussed in other BLS publications, they are discussed only briefly here. See Gullickson and Harper, "Multifactor productivity."

The concepts and computational methods presently used are largely identical to those used previously. There are, however, minor methodological revisions which cause slight changes throughout the series. These are:

(a) *The use of hours at work rather than hours paid as a basis for the labor input*. This lowers the levels of hours and, because vacations and other paid leave have varied through the postwar period, adds a trend change. Also, because labor cost is unaffected, there is a corresponding adjustment (opposite direction) to labor price.

(b) *The exclusion of several classes of indirect business taxes from capital cost*. Previously, all such taxes were considered to be associated with capital, including sales taxes and large Federal excises on liquor, tobacco, and petroleum products. Now, only taxes explicitly related to capital stocks, such as property and motor vehicle taxes, are included.

(c) *Nonprofit institutions are removed from industries (and the aggregates)*. This is to be in accordance with the definitions used for other BLS multifactor statistics, such as those for the private business, nonfarm business, and manufacturing aggregates.

[4] For a thorough discussion of capital measurement procedures, see *Trends in Multifactor Productivity, 1948–81*, Bulletin 2178 (Bureau of Labor Statistics, 1983).

[5] For a discussion of BLS rental prices, see Michael J. Harper, Ernst R. Berndt, and David O. Wood, "Rates of Return and Capital Aggregation Using Alternative Rental Prices," in Dale W. Jorgenson and Ralph Landau, eds., *Technology and Capital Formation* (Cambridge, MA, The MIT Press, 1989), pp. 332–72.

[6] Leo Tornqvist, "The Bank of Finland's consumption price index," *Bank of Finland Monthly Bulletin*, 10 (1936) pp. 1–8. References to this index form are given by Dale Jorgenson, Frank Gollop, and Barbara Fraumeni, in *Productivity and U.S. Economic Growth* (Cambridge, MA, Harvard University Press, 1987).

[7] See Ronald W. Shephard, *Theory of Cost and Production Functions* (Princeton, NJ, Princeton University Press, 1953). Shephard showed that, for a production function characterized by constant returns to scale, productivity can be computed as the difference between input and output prices if firms are minimizing costs.

[8] See for example the *Productivity and Costs*, USDL 91-428 (U.S. Department of Labor), September 1991.

[9] Where A is aggregate productivity and A_i, Q_i and X_i are productivity, net output (real value added), and primary inputs (capital and labor) for r industries,

$$\begin{aligned} A &= \Sigma_{i=1,r} Q_i / \Sigma_{i=1,r} X_i \\ &= (Q_1/\Sigma_{i=1,r} X_i) + (Q_2/\Sigma_{i=1,r} X_i) + \ldots + (Q_r/\Sigma_{i=1,r} X_i) \\ &= (Q_1/X_1)(X_1/\Sigma_{i=1,r} X_i) + (Q_2/X_2)(X_2/\Sigma_{i=1,r} X_i) + \ldots \\ &\quad + (Q_n/X_n)(X_n/\Sigma_{i=1,r} X_i) \end{aligned}$$

The $X_i/\Sigma_{i=1,r} X_i$ terms are industry shares in total primary inputs (capital and labor), so aggregate productivity is the weighted average of the industry productivity measures, with weights based on input quantities.

[10] Private business multifactor productivity is defined as the real gross product of the private business sector per unit of combined labor and capital services. It is similar to the measure published by BLS in that both are based on output series defined as real gross national product, adjusted to exclude the "rest-of-world" output and certain nonbusiness output items included in real GNP, but not properly attributable to private business (the real gross product of general governments and government enterprises, the household industry and nonprofit institutions, owner-occupied housing, and the statistical discrepancy).

For comparability with manufacturing, the business multifactor productivity measure shown here is based on a real GNP series which is a Tornqvist aggregate rather than the fixed-weighted composite commonly associated with the National Income and Product Accounts. In the accounts, deflated value aggregates such as real GNP are constructed by deflating at the most detailed level possible and then summing the deflated values. This yields a sum which, when indexed, is equivalent to a weighted average of the detailed indexes, with constant weights taken from the deflator base year.

The real GNP measure used here employs the annually changing Tornqvist weighting procedure used for aggregation elsewhere in the multifactor productivity program. The maximum detail available in the published National Income Products Accounts are used—approximately 200 series on deliveries to final users (households, investors, net exports, and State and local governments), and 134 deflator series.

It should be noted that the private business multifactor productivity measure based on the fixed-weighted output aggregate differs from that shown here. For example, average growth in the former for the 1949–73 period was slower (2.1 percent per year, compared with 2.4 percent in multifactor productivity measure based on the Tornqvist output aggregate), and for the 1979–88 period, it was faster (0.9 percent per year, compared to 0.8). These systematic differences are largely attributable to the rapid decline in computer prices together with the fact that the National Income Products Accounts are bench-marked to 1982 prices.

[11] Machinery, except electrical, includes producers of computer equipment for which prices have proven particularly hard to measure. Whenever the nature of products changes rapidly over time, price and output change cannot be measured in a straight-forward way simply because outputs in successive periods are not comparable. Accordingly, measures of the output of most kinds of computer equipment in the National Income and Product Accounts must be constructed using one of several methods other than direct price collection and deflation. Most notable among these is a regression index, which is formed "from the coefficients for year and technology class in an hedonic function, which relates prices paid for computers to quality characteristics, such as speed and memory size." Thus, the output of some computing equipment is measured essentially in terms of what the machines can do. See David W. Cartwright and Scott D. Smith, "Deflators for Purchases of Computers in GNP: Revised and Extended Estimates, 1983–88," *Survey of Current Business*, November, 1988, pp. 22–23.

The hedonic index for computing equipment, which is used beginning in 1969, has since resulted in an average annual price decline of about 12 percent and an average annual output increase of more than 30 percent for the 4-digit industry, electronic computing equipment (3573). These extraordinary output growth rates are largely responsible for the rapid productivity growth in machinery, except electrical shown in tables 3 and 4: 4.4 percent per year on average from 1979 to 1988—over twice the rate of any other two-digit industry in the period.

It is interesting to note that if the measured productivity growth rate for machinery, except electrical were more similar to rates for other industries in the period—say half the measured rate—and the contribution correspondingly less than that shown in table 5, average productivity growth rates for the manufacturing and private business aggregates would be reduced by as much as 0.2 percentage points per year for the 1979–88 period. Thus, the manufacturing average for the 1979–88 period would be reduced to 1.4 (from 1.6 percent per year) and the dismal performance of the private business sector—0.8 percent per year, compared with 2.0 percent for the 1949–79 period—would be even worse, at 0.6 percent per year.

APPENDIX: Aggregate and industry productivity change.

The framework used to attribute business productivity change to industries was proposed by Evsey D. Domar. See "On the Measurement of Technological Change," *The Economic Journal*, December 1961, pp. 709–29.

Domar noted that, while it is preferable to define productivity measures for an industry in terms of all inputs including materials bought from other industries, productivity for the economy as a whole should be defined in terms of only primary inputs—capital and labor. This is because materials and services obtained from other producers, called intermediates, are strictly internal to the aggregate, and do not, in themselves satisfy the needs of final users and therefore should not figure in the measurement of the economy's efficiency. Domar then proceeded to work out a relation between aggregate and industry measures and showed that this relation was invariant to the degree of integration of industries.

The relation between industry productivity measures, defined in terms of all inputs, and aggregate measures defined in terms of only capital and labor is the following, according to Domar: The rate of growth of multifactor productivity for the aggregate (the residual) equals the sum of productivity growth rates for the component industries; each industry growth rate weighted by the *ratio of the value of the output of the industry to the value of the output of the aggregate*. Domar demonstrated this relation using as an example an economy consisting of two vertically integrated industries—one selling to final users, the other selling to the first industry. Assuming homogeneous production functions of the Cobb-Douglas type and competitive markets so that input prices equal marginal products, equations (1) and (2) describe the two industry production processes. If Y_1 is the output of the first industry (all sold to final demand), R_2 the output of the second (all bought by the first industry), and α, β, and γ are factor shares in industry values of production, then:

$$(1) \quad dlnY_1/dt = dlnA_1/dt + \alpha_1 dlnL_1/dt + \beta_1 dlnK_1/dt + \gamma_1 dlnR_2/dt$$

and

$$(2) \quad dlnR_2/dt = dlnA_2/dt + \alpha_2 dlnL_2/dt + \beta_2 dlnK_2/dt$$

Substituting (2) into (1) gives the change in the output of the economy as a whole (equal to the change in Y_1):

$$(3) \quad dlnY/dt = dlnA_1/dt + \alpha_1 dlnL_1/dt + \beta_1 dlnK_1/dt + \gamma_1 dlnA_2/dt + \gamma_1\alpha_2 dlnL_2/dt + \gamma_1\beta_2 dlnK_2/dt$$

Productivity change for the economy as a whole, that is, the residual of output change not accounted for by change in inputs, is:

$$(4) \quad dlnA/dt = dlnA_1/dt + \gamma_1 dlnA_2/dt$$

Aggregate productivity change is therefore a weighted sum of productivity growth rates for the two industries, the sum of the weights, unity and γ_1, exceeding one. Y_1, the output provided by the first industry to final demand, represents all sales to final demand (the value of aggregate output); and γ_1 is the share of R_2 in the value of Y_1. Thus, the weights given to $dlnA_1$ and $dlnA_2$ in the summation are in both cases equal to the ratios of the values of industry production to aggregate output.

Domar went on to show that the relation still held when (a) more than two industries were involved in the vertically integrated economy; (b) an industry uses part of its own output as an input; (c) industries use each other's outputs as inputs.

Another way of looking at the relation of industry and aggregate multifactor productivity change is to compare the changes in industry and aggregate productivity resulting from a given technical change, for example, a reduction in the use of one input at the industry level. Again assuming homogeneous industry and aggregate production functions and competitive input markets, the change in aggregate productivity can be written:

$$(5) \quad dlnA/dt = dlnY/dt - \Sigma_{n=k,l,} \Sigma_{j=1,r} (p_n N_{nj} / \Sigma p_j Y_j)(dlnN_{nj}/dt)$$

As before, output for the aggregate (Y) is that provided to final users—private households, investors, government consumers, and net exports—and excludes transactions between industries; inputs (N) to the aggregate are similarly defined as the primary inputs of labor and capital services used by r industries.[1] Prices of inputs and output are p_n and p_j, respectively; Y_j are industry deliveries to final demand; $p_n N_{nj}/\Sigma p_j Y_j$ are the shares of n inputs to j industries in GNP.

Industry multifactor productivity measures are:

$$(6) \quad dlnA^j_z/dt = dlnZ_j/dt - \Sigma_m(p_m M_m/p_j Z_j)(dlnM_{mj}/dt) - \Sigma_{n=k,l}(p_n N_{nj}/p_j Z_j)(dlnN_{nj}/dt)$$

As with the industry measures specified by Domar, these measures are in terms of gross output: industry output (Z) *includes* deliveries to other industrial consumers as well as final users; inputs are primary inputs of labor and capital services (N) and inputs of intermediate products obtained from other domestic industries (M).

To illustrate the relationship between sector and aggregate multifactor productivity measures, consider a change in the use of one primary input by industry j, which reduces its use of one of its primary inputs, N_{nj}, without reducing output or changing its use of any other input. The change in industry productivity attributable to this reduction is equal to (the negative of) the change in the input multiplied by the share of that input in the industry's total cost. Similarly, the change in aggregate productivity due to the same reduction is (the negative of) the change in the input multiplied by its share in the aggregate's total costs. Thus, the ratio of aggregate to industry multifactor productivity change due to this one input reduction is equal to the ratio of change in industry input to change in aggregate input, which is in turn equal to the ratio of the cost share of N_{nj} in the total cost of all inputs to the industry to N_{nj}'s share in the aggregate cost of production:

$$(7)\quad (dlnA^j_z/dt)/(dlnA/dt) = (p_nN_{nj}/p_jZ_j)(dlnN_{nj}/dt)/ (p_nN_{nj}/\Sigma_{j=1,r}p_jY_j)(dlnN_{nj}/dt) = (\Sigma_{j=1,r}p_jY_j)/(p_jZ_j)$$

Thus, the effect on aggregate productivity of changes in productivity at the industry level can be calculated as:

$$(8)\quad dlnA\,/dt = dlnA^j_z/dt(p_jZ_j)/(\Sigma_{j=1,r}p_jY_j)$$

that is, as the industry rate of change multiplied by the ratio of industry-to-aggregate output both in current values.

In this example, the technological change in question was a *ceteris paribus* change in the use of one input not obtained from other domestic producers, that is, either a labor or capital service. Production-process advances may involve changes in the use of domestically produced intermediates also, so we need to establish that the relation between industry and aggregate productivity change given earlier still holds in that case. Because these transactions are internal to the aggregate and are considered neither input nor output in the aggregate productivity measures, changes in their use cannot directly affect these aggregate measures. The relation between sector and aggregate multifactor productivity change when these intermediates are involved is therefore less clear intuitively.

In fact, the relationship between sector-level and aggregate measures given by equation (8) still can be used even if changed input use at the sector level involves intermediates. What is required is that changed use of intermediates be considered to represent a proportional change in the use of primary inputs by their upstream producers. Thus, the effect on sector j's measured productivity of a reduced use of materials bought from other domestic producers in equation (5) can be recast in terms of the primary inputs underlying these materials:

$$(9)\quad \Sigma_m(p_mM_{mj}/p_jZ_j)(dlnM_{mj}/dt) = \Sigma_m\Sigma_{k=1,r}(p_nN_{njk}/p_jZ_j)(dlnN_{njk}/dt)$$

where N_{njk} represents the primary input used by upstream producer k as a direct or indirect consequence of the consumption of intermediate input m by industry j (M_{mj}). If supplying industries reduce their use of intermediate and primary inputs in proportion to declines in their output levels resulting from changes in demand by downstream consumers, then there may be seen to be a linear relation between intermediate transactions and the ultimate use of primary inputs. Thus, savings in intermediate inputs at the sector level may be viewed as contributing to aggregate multifactor productivity growth in a way indistinguishable from savings in primary inputs.

The value of any transaction (in the present example, the value of an intermediate input by j) is equal to payments for primary inputs by all upstream industries contributing, directly or indirectly, to its production.

The notable feature of the relationship between industry and aggregate productivity change where intermediates are involved is that changes in the use of intermediate products by one industry are assumed to represent proportional changes in primary inputs (used by the direct and indirect suppliers of those inputs). That is, it is assumed that productivity levels of upstream suppliers will remain constant as their output levels change. If supplying industries do not adjust primary input levels proportionally when their output level changes—which doubtless is the case to some degree with regard to both labor and capital—we are attributing reductions in primary inputs which do not necessarily occur. However, the method still "adds up"; the attributed, not actual reductions in primary inputs upstream which correspond to the reduced use of materials by intermediate industrial consumers are offset by measured multifactor productivity declines in the upstream supplying industries. It is useful to attribute potential factor savings to industries which created that potential and, while there may be lags in primary input reductions in response to output declines, there is a reasonable likelihood that these reductions occur in the long term.

Footnote to the appendix

[1] It is conventional in measures of aggregate productivity to base the output measure on real gross domestic product (with exclusions to reduce the measure to business output) and to define inputs in terms of primary inputs, that is, capital and labor services. In the National Income and Product Accounts, gross domestic product reflects deliveries to "net exports," that is, the difference between exports and imports of goods and services. It has been pointed out that in keeping with the principle that inputs should include all items obtained from outside the sector, for the business sector they should properly include imported intermediates; similarly, these imported raw materials, components, and so forth, should not be netted out of exports in arriving at real gross domestic product. See Frank M. Gollop, "Growth Accounting in an Open Economy," *Boston College Working Papers in Economics* (Boston, MA, Boston College, March 1981). The value and quantity of such imports can be estimated from published National Income Products Accounts data and, despite growth in recent years, are still too small to affect aggregate productivity measures visibly.