Recent changes in the growth of U.S. multifactor productivity

Since 1979, multifactor productivity growth has recovered completely only in manufacturing; for the rest of private business, growth has recovered partially, but remains below the 1948–73 trend rate

EDWIN DEAN AND KENT KUNZE

The dramatic slowdown in productivity growth that began about 1973 has been the focus of much analysis and discussion. In recent months, this discussion has taken on new life, as analysts continue to probe the influence of U.S. productivity growth on the country's competitiveness in world trade. Other commentators have raised the possibility that the slowdown has ended and productivity growth has resumed its earlier pace.

The present article contributes to the discussion by presenting and analyzing recent Bureau of Labor Statistics measures of growth in multifactor productivity in the United States. It also presents preliminary results of BLS studies of factors that have affected productivity change. Special attention is given to the productivity growth record for recent years, to examine whether productivity might have resumed its pre-1973 pace.

BLS multifactor measures

In 1983, the BLS introduced measures of multifactor productivity for three major sectors of the U.S. economy—private business, private nonfarm business, and manufacturing. Since that year, annual news releases have provided current multifactor productivity measures. Because the methods used to develop these measures have been described in two 1983 publications,[1] only a brief summary is presented here.

In the BLS measures, growth in multifactor productivity is measured as the difference between the growth rate of output and the growth rate of combined capital and labor inputs.[2] Growth in multifactor productivity reflects increase in output due to factors other than growth in capital and labor inputs.[3] Multifactor productivity calculated in this way provides a numerical answer to the question: What is the portion of the growth rate of output that cannot be accounted for by the growth rate of combined inputs?

The measured multifactor productivity growth rates reflect changes in all influences on output other than the inputs. They reflect changes in technology, including changes that result from research and development activities; economies of scale; changes in the management or organization of resources; and changes in the skills and efforts workers bring to the job.

Multifactor productivity is closely related to the commonly used concept of labor productivity, or output per unit of labor input. It can be shown that, under certain assumptions,[4] growth in labor productivity is equal to growth in multifactor productivity plus another factor. That factor is the growth in capital input per labor hour times the share of capital income in the value of output—or capital's share, for short. It follows that growth in labor productivity can be decomposed into two parts, the

Edwin Dean is chief of the Division of Productivity Research, Bureau of Labor Statistics. Kent Kunze is an economist in the same division.

part due to growth in multifactor productivity and the part due to growth in capital input per labor hour or the capital-labor ratio. Over long periods in most economies, all three of these terms will be positive, so that a positive growth rate in labor productivity is the sum of positive growth in multifactor productivity plus the positive growth rate in the capital-labor ratio times the capital share in output. (Of course, it is possible for one or more of these growth rates to be negative.)

This relationship can be expressed in an equation:

$$(1)\quad \left(\frac{\dot{Q}}{Q} - \frac{\dot{L}}{L}\right) = \frac{\dot{A}}{A} + s_K\left(\frac{\dot{K}}{K} - \frac{\dot{L}}{L}\right)$$

where Q is output, L is labor hours, K is capital input, s_k is capital's share, and A represents the state of technology. A dot over a variable indicates the rate of change of the variable with respect to time. The ratio $\dot{K}/K$ is therefore the *percentage* rate of change of capital.

The term $\frac{\dot{Q}}{Q} - \frac{\dot{L}}{L}$ is the percentage rate of change over time in labor productivity, Q/L (output per hour). Similarly, $\dot{A}/A$ is the percentage rate of change in multifactor productivity, or output per unit of combined labor and capital inputs. The term $\frac{\dot{K}}{K} - \frac{\dot{L}}{L}$ is the percentage rate of change in capital input per hour, the capital-labor ratio, while s_k is capital's share. (Capital's share, s_k, and labor's share, s_l, both are fractions and their sum exhausts the total value of output; it follows that $s_k + s_l = 1$.)

Equation 1 expresses the relationship described earlier: The percentage rate of change in labor productivity, $\frac{\dot{Q}}{Q} - \frac{\dot{L}}{L}$, is equal to the percentage rate of change in multifactor productivity, $\dot{A}/A$, plus the percentage rate of change in the capital-labor ratio, $\frac{\dot{K}}{K} - \frac{\dot{L}}{L}$, times the share of capital in output, s_k.

Equation 1 decomposes the change in the familiar labor productivity ratio, Q/L, into the role of multifactor productivity and the role of capital input relative to labor input (the capital-labor ratio).[5]

Long-term trends

Annual measures of productivity change often are sensitive to cyclical effects. It is helpful to look at long-term trends in order to minimize the effects of cyclical disturbances. In addition, long-term trends help to provide a benchmark for gauging the relative performance of productivity growth for shorter periods. Such a gauge has become increasingly important with the deceleration of productivity growth over the last 15 years.

From 1948 to 1986, multifactor productivity in the private business sector increased at an average rate of 1.4 percent per year (table 1). This growth reflects a 3.2-percent average annual increase in output and a 1.8-percent rate of growth of combined inputs of labor and capital services. Labor services (hours) in private business increased at a rate of 0.9 percent per year, and capital services grew 3.4 percent annually. The capital-labor ratio grew 2.4 percent per year.

The nonfarm business sector had a pattern of productivity growth for the 1948–86 period that was similar to that of private business. Multifactor productivity increased 1.1 percent annually for the entire period as output rose 3.3 percent yearly and combined inputs grew at a 2.1-percent annual rate. Hours increased 1.4 percent annually in private nonfarm business, a faster rate of growth than in private business, reflecting a decline in hours in farm production. Inputs of capital services increased 3.6 percent per year in private nonfarm business.

In manufacturing, multifactor productivity grew at an annual rate of 1.9 percent between 1948 and 1986. Output increased at a 3.3-percent rate and combined inputs grew 1.4 percent yearly. Labor hours rose at an annual rate of only 0.6 percent, and capital services grew 3.4 percent per year.

The measured relationship between multifactor productivity and labor productivity was approximately the same for the three sectors. Multifactor productivity growth accounted for 60 to 70 percent of labor productivity growth during the postwar period, with the remainder

Table 1. Average annual growth rates of multifactor productivity and related measures for private business, private nonfarm business, and manufacturing, 1948–86

[In percent]

Measure	Private business[1]	Private nonfarm business[1]	Manufacturing
Productivity:			
Multifactor productivity[2]	1.4	1.1	1.9
Output per hour of all persons	2.3	1.9	2.7
Output per unit of capital services	–.1	–.2	–.1
Output	3.2	3.3	3.3
Inputs:			
Labor hours	.9	1.4	.6
Capital services	3.4	3.6	3.4
Combined units of labor and capital inputs[3]	1.8	2.1	1.4
Capital-labor ratio[4]	2.4	2.1	2.9
Contribution of capital intensity[5]	.9	.8	.8

[1] Excludes government enterprises.
[2] Output per unit of combined labor and capital input.
[3] Hours of all persons combined with capital service input index, weighted by labor and capital shares.
[4] Capital services per hour of all persons.
[5] Changes in capital-labor ratio times capital's share in the value of output.

Table 2. Shares of capital and labor income in the value of output, private business, private nonfarm business, and manufacturing, selected years, 1948–86

[In percent]

Sector	Income shares			
	1948	1973	1979	1986
Private business:				
Capital	36.1	35.7	35.0	36.2
Labor	63.9	64.3	65.0	63.8
Private nonfarm business:				
Capital	35.5	34.2	33.9	35.4
Labor	64.5	65.8	66.1	64.6
Manufacturing:				
Capital	32.2	28.7	26.4	29.4
Labor	67.8	71.3	73.6	70.6

arising from an increase in the capital-labor ratio and changes in capital's share (the share of capital income in the value of output, s_k). Because capital's share was fairly stable over time (table 2), changes in this share had little effect on labor productivity. In manufacturing, multifactor productivity growth accounted for the largest proportion of labor productivity increase, 70 percent. Manufacturing also had the fastest rate of growth of the capital-labor ratio; however, capital's share was generally lower in manufacturing than in the other sectors, and this tended to dampen the influence on labor productivity of growth in the capital-labor ratio. For private business and private nonfarm business, growth in multifactor productivity accounted for about 60 percent of labor productivity increase during the period.

The productivity slowdown

The post-1973 decline in the growth rate of both multifactor and labor productivity has been a source of persistent concern for business leaders, economists, and policymakers. A plethora of books and articles has appeared analyzing the probable causes and consequences of the productivity slowdown.[6] The following discussion examines the magnitude of the slowdown, using the most current measures.

Between 1948 and 1973, the United States enjoyed a sustained period of strong productivity growth. Multifactor productivity in the nonfarm business sector rose at an annual rate of 1.7 percent during this period (table 3). This, coupled with the increase in the capital-labor ratio, produced an annual rate of growth of labor productivity of 2.5 percent. For the private business sector, the productivity advance was even greater: Extra growth occurred because of a shift of workers out of the farm sector, which had relatively low productivity, to the nonfarm sector, which had higher productivity.[7]

The manufacturing sector also experienced sustained high growth rates of both multifactor and labor productivity in the postwar period. The rapid advance in labor productivity was a reflection of both a high rate of multifactor productivity growth—2.0 percent annually—and a high rate of growth in the capital-labor ratio—2.6 percent per year.

Between 1973 and 1979, the Nation's rate of productivity growth changed drastically. Output per hour in private business increased only 0.6 percent annually and multifactor productivity rose only 0.1 percent per year. (See table 3 and chart 1.) In private nonfarm business, output per hour increased at an annual rate of 0.5 percent, while multifactor productivity did not grow at all.

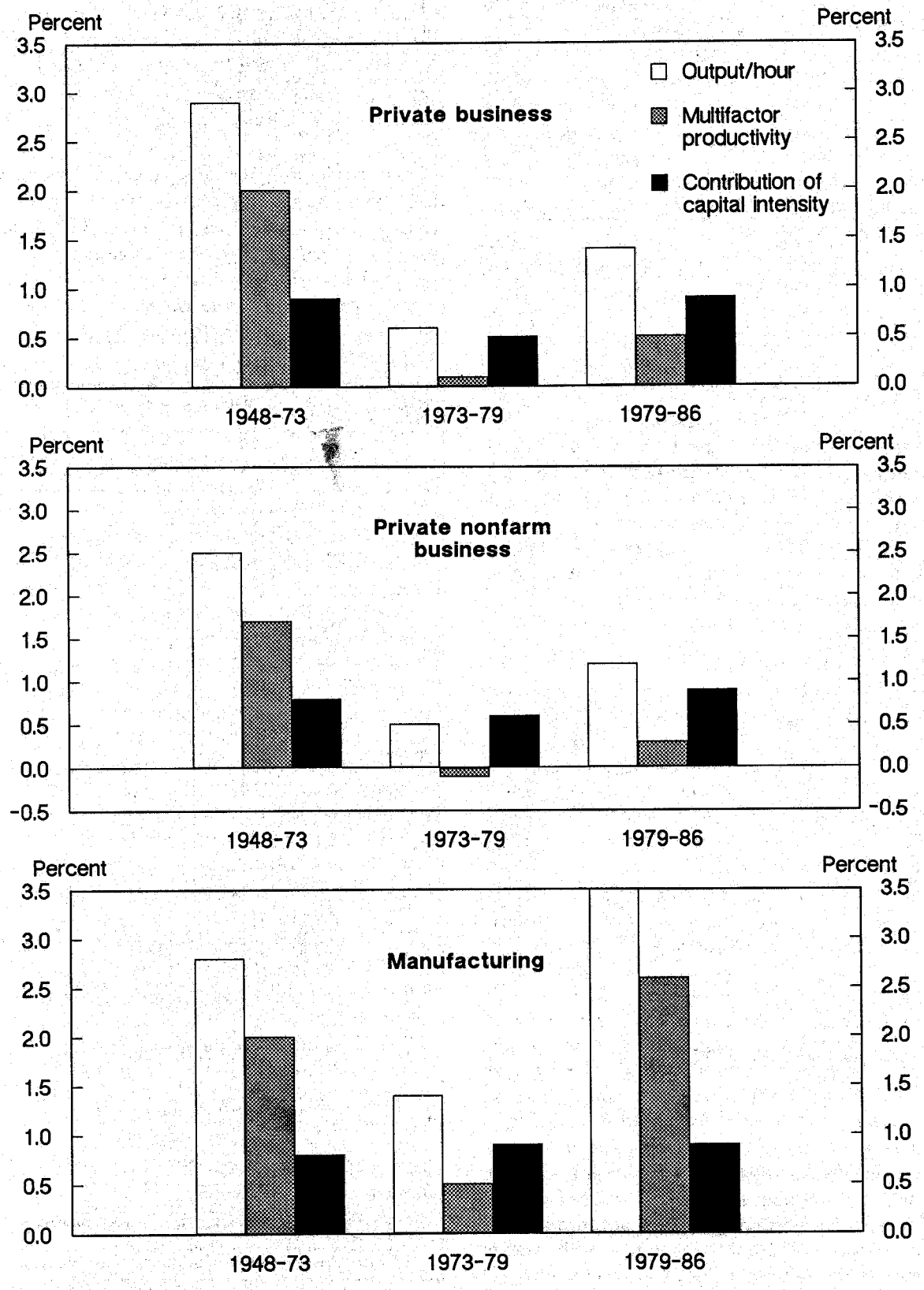
Labor productivity continued to show some advance in these two sectors only because of continued, though slower, growth in capital intensity (the capital-labor ratio). In private business, the average annual increase in the capital-labor ratio fell from 2.6 percent in the previous period to 1.5 percent in the 1973–79 period.

Table 3. Average annual growth rates of multifactor productivity and related measures for private business, private nonfarm business, and manufacturing, 1948–73, 1973–79, and 1979–86

Sector and measure	Period		
	1948–73	1973–79	1979–86
Private business[1]			
Productivity:			
Multifactor productivity[2]	2.0	0.1	0.5
Output per hour of all persons	2.9	.6	1.4
Output per unit of capital services	.3	-.9	-1.0
Output	3.6	2.5	2.5
Inputs:			
Labor hours	.7	1.9	1.1
Capital services	3.3	3.4	3.6
Combined unit of labor and capital inputs[3]	1.6	2.4	1.9
Capital-labor ratio[4]	2.6	1.5	2.5
Contribution of capital intensity[5]	.9	.5	.9
Private nonfarm business[1]			
Productivity:			
Multifactor productivity[2]	1.7	-.1	.3
Output per hour of all persons	2.5	.5	1.2
Output per unit of capital services	.3	-1.1	-1.3
Output	3.8	2.5	2.4
Inputs:			
Labor hours	1.3	2.1	1.2
Capital services	3.5	3.7	3.7
Combined unit of labor and capital inputs[3]	2.0	2.6	2.1
Capital-labor ratio[4]	2.2	1.6	2.5
Contribution of capital intensity[5]	.8	.6	.9
Manufacturing			
Productivity:			
Multifactor productivity[2]	2.0	.5	2.6
Output per hour of all persons	2.8	1.4	3.5
Output per unit of capital services	.2	-1.8	.1
Output	3.9	1.9	2.2
Inputs:			
Labor hours	1.1	.5	-1.2
Capital services	3.7	3.8	2.3
Combined unit of labor and capital inputs[3]	1.8	1.4	-.4
Capital-labor ratio[4]	2.6	3.3	3.5
Contribution of capital intensity[5]	.8	.9	.9

[1] Excludes government enterprises.
[2] Output per unit of combined labor and capital input.
[3] Hours of all persons combined with capital service input index, weighted by labor and capital shares.
[4] Capital services per hour of all persons.
[5] Changes in capital-labor ratio times capital's share in the value of output.

Chart 1. Average annual growth rates of labor productivity, multifactor productivity, and the contribution of capital intensity, selected periods, 1948-86



Similarly, in nonfarm business, the growth rate fell from 2.2 percent annually over the period 1948–73 to 1.6 percent in 1973–79. Only in manufacturing did the capital-labor ratio continue to increase rapidly. In fact, this ratio accelerated to a growth rate of 3.3 percent annually, up from a 2.6-percent rate in the earlier period.

Of the total deceleration in labor productivity growth in private business (2.3 percentage points), over 80 percent (1.9 percentage points) was a result of the deceleration in multifactor productivity growth. Less than 20 percent of the reduction in the rate of labor productivity increase was due to the decline in the growth rate of the capital-labor ratio. The same pattern held in private nonfarm business.

In manufacturing, the deceleration of multifactor productivity growth accounted for more than the full decline in the labor productivity growth rate. Because the rate of increase in the capital-labor ratio actually accelerated during the period, labor productivity growth slowed less than multifactor productivity growth.

The recovery: 1979–86

During the most recent period, 1979 to 1986, there has been a partial recovery in productivity growth. The recovery must be considered incomplete because growth rates for both multifactor and labor productivity in private business and private nonfarm business have risen above the low rates of 1973–79 but have not reached the pre-1973 rates. In manufacturing, however, multifactor and labor productivity growth rates have surpassed the pre-1973 rates.

In private business and private nonfarm business, the rate of increase in labor hours in 1979–86 declined relative to the 1973–79 rate, while capital services grew steadily, resulting in an acceleration of growth in the capital-labor ratio. These developments contributed to the more rapid rise of labor productivity. A modest increase in multifactor productivity growth also assisted the growth of labor productivity. In manufacturing, however, the rise of more than 2 percentage points, from 1.4 percent to 3.5 percent, in labor productivity growth reflected an increase in multifactor productivity growth of 2 percentage points, with no noticeable assistance from the capital-labor ratio.

Elements of multifactor productivity change

It is noted above that the measured growth rates of multifactor productivity reflect changes in technology (the processes used to produce output); economies of scale; organizational or management changes; and the skills workers bring to the job (generally acquired through schooling and experience). In addition, multifactor productivity reflects any errors made in measurement of the inputs (hours and capital services) and the output. BLS has conducted and continues to conduct research in these areas to gain understanding of the multifactor productivity changes and also to eliminate possible measurement error. The present areas of research include the measurement of the effects of research and development (R&D) expenditures on productivity growth; the measurement of the changing amounts of education and experience that workers possess and the subsequent effects on productivity growth; and a better measure of hours, which reflects the actual number of labor hours spent at the workplace as opposed to the hours (including vacations and other leave time) for which workers are paid.

Increased expenditures on R&D are considered to be a prime factor in the creation of more efficient technologies. Relative expenditures on R&D in nonfarm business slowed substantially in the 1970's. The total stock of R&D,[8] which had increased 7.8 percent annually between 1948 and 1973, rose 4.0 percent per year between 1973 and 1979. From 1979 to 1985, the growth rate of the R&D stock accelerated moderately to 4.4 percent.[9] However, results of the empirical work also show that the post-1973 changes in the growth rates of the stock had almost no effect on post-1973 rates of change in multifactor productivity. The research results for manufacturing are quite similar to those for nonfarm business.

Preliminary work on the productivity effects of worker experience and education shows that a small but measurable portion of the slowdown was attributable to changes in the composition of the work force. Increase in workers' education and experience is positively correlated with growth in output and productivity. During the late 1960's and throughout the 1970's, the work force expanded rapidly, resulting in an increased proportion of younger, inexperienced workers. At the same time, more and more workers attained higher levels of education, tending to counter some of the consequences of the influx of inexperienced workers.

Preliminary results indicate that the contribution to multifactor productivity growth of changes in labor composition in private business dropped from an average of 0.2 percent per year in 1948–73 to zero in 1973–79.[10] The rise in the proportion of less experienced workers ceased after 1979, although there continued to be an increase in the average years of schooling of the work force.[11] After 1979, labor composition changes contributed about 0.3 percent per year to multifactor productivity growth—about as much as they had before 1973.[12] Similar preliminary results hold for private nonfarm business, while results for manufacturing are not presently available.

Beginning in 1982, BLS began collecting data on the ratio of hours at work to hours paid for production and nonsupervisory workers in nonagricultural establishments. One purpose of this survey is to develop new data

on labor hours for use in productivity measurement. Only 15 percent of total labor hours, as presently measured in the labor productivity and multifactor measures, are based on an "hours at work" concept, the concept most consistent with productivity measurement. This portion of total hours is derived primarily from the Current Population Survey, a survey of households conducted for BLS by the Bureau of the Census. The remaining 85 percent of the hours are based on an "hours paid" concept; this portion of total hours is derived from the Current Employment Statistics survey, a BLS establishment-based program. Hence, the current productivity measures, as presented in tables 1 and 3, reflect predominately an "hours paid" concept.

The growth rates of hours at work and hours paid may, of course, differ over time. If, for example, hours paid increase faster than hours at work, then productivity growth will be underestimated. Old estimates of the historical trend of the hours-at-work/hours-paid ratio show a small divergence in the growth rates of the two measures. Between 1948 and 1973, the ratio decreased 0.1 percent annually, and from 1973 to 1979, it fell 0.2 percent per year. These computations suggest that the slowdown in labor productivity growth is 0.1 percentage point less than recorded in table 3. From 1979 to 1986, the ratio of hours at work to hours paid remained virtually unchanged.[13] Hence, productivity in nonfarm business has increased as presently reported. The results for manufacturing indicate that changes in the ratio of hours at work to hours paid had effects on productivity, as presently reported, of 0.1 percent or less for the periods under examination.

Summary

BLS measures show that, after a period of strong growth in both multifactor productivity and output per hour from 1948 to 1973, there followed a period of little or no increase from 1973 to 1979. Since 1979, productivity growth has recovered partially in the private business and the private nonfarm business sectors. Only in manufacturing has the recovery been complete.

An analysis of the 1973–79 slowdown in labor productivity shows that the major part of the slowdown cannot be explained by any of the factors examined to date in the BLS research program. This conclusion holds for all three of the sectors examined here—private business, private nonfarm business, and manufacturing. In this regard, the BLS results coincide with the analyses of most private researchers. Three of the four factors discussed in this article—growth in the capital-labor ratio, changes in labor composition, and a decline in the ratio of hours at work to hours paid—contributed in modest ways to the slowdown, while the fourth, the decline in the growth rate of R&D expenditures, did not. The major component of the deceleration in labor productivity was a slowdown in multifactor productivity that was not explained by these four factors.

The partial recovery of labor productivity growth in private business and private nonfarm business after 1979 can be attributed largely to increases in the capital-labor ratio and to changes in the composition of the labor force. The other two factors—R&D expenditures and hours at work—did not contribute to this recovery. For manufacturing, the complete recovery in labor productivity growth after 1979 was due predominately to increased growth in multifactor productivity. □

FOOTNOTES

ACKNOWLEDGMENT: The authors thank Steven Rosenthal, who performed the computer calculations underlying this analysis.

[1] *Trends in Multifactor Productivity, 1948–81*, Bulletin 2178 (Bureau of Labor Statistics, 1983); and Jerome A. Mark and William H. Waldorf, "Multifactor productivity: a new BLS measure," *Monthly Labor Review*, December 1983, pp. 3–15.

[2] Output is defined as real gross product originating in a given sector, which is net of its intermediate inputs. For consistency with this output definition, the inputs include only the primary inputs of labor and capital, that is, they exclude intermediate inputs such as energy, nonenergy materials, and business services.

In measures of multifactor productivity growth for detailed industries, output is more appropriately measured as deflated gross output of the industry, rather than deflated gross product originating. For consistency with this output measure, inputs for detailed industries should include purchased intermediate inputs as well as the primary inputs of labor and capital. For further discussion of these concepts and implementation of the measurement methods, see William Gullickson and Michael Harper, "Multifactor productivity in U.S. manufacturing, 1949–83," *Monthly Labor Review*, October 1987, pp. 18–28; and Mark K. Sherwood, "Performance of multifactor productivity in the steel and motor vehicles industries," *Monthly Labor Review*, August 1987, pp. 22–31.

[3] The multifactor productivity measurement formula is derived from an assumed production relationship: $Q(t) = A(t)\, f[K(t), L(t)]$, where $Q(t)$ is real output, $K(t)$ is real capital input, $L(t)$ is real labor input, and $A(t)$ is an index of neutral technological progress or multifactor productivity. The development of this assumed production relationship into a measurement formula is based on the assumptions of perfect competition, Hicks neutral technical change, and constant returns to scale. Equation 1 in the text is an example of the measurement formulae that can be derived from this assumed production relationship. For additional discussion of this model and the assumptions underlying it, see *Trends in Multifactor Productivity, 1948–81*; Mark and Waldorf, "Multifactor productivity: a new BLS measure"; Gullickson and Harper, "Multifactor productivity in U.S. manufacturing, 1949–83"; and Susan Powers, "The role of capital discards in multifactor productivity measurement," *Monthly Labor Review*, forthcoming.

[4] As mentioned in the preceding note, it is assumed that the production function is characterized by Hicks neutral technical change and constant returns to scale, and that there is perfect competition in input and output markets.

[5] The BLS multifactor productivity measures introduced in 1983 were extensively revised in 1986. The recent measures are based on revised basic data as well as a methodological improvement. The data revisions consist of new output data for 1948 to 1984 and new capital input data for the same years. The methodological revision is an improvement in

the technique for measuring capital inputs. These improvements are described in detail in the appendix to this article.

The 1986 revisions were first reflected in the data presented in an October 1986 news release, "Multifactor Productivity Measures, 1985," USDL 86–402 (Bureau of Labor Statistics, Oct. 2, 1986). Further minor revisions were reflected in the October 1987 news release, "Multifactor Productivity Measures, 1986," USDL 87–436 (Bureau of Labor Statistics, Oct. 13, 1987). The measures presented in tables 1, 2, and 3 of this article are consistent with the October 1987 release.

[6]For examples, see the numerous references in Edward Denison, *Trends in American Economic Growth, 1928–1982* (Washington, The Brookings Institution, 1985).

[7]See J.R. Norsworthy and L.J. Fulco, "Productivity and costs in the private economy, 1973," *Monthly Labor Review*, June 1974, pp. 3–9. The authors found an increase in labor productivity growth of 0.3 percentage points in the private economy between 1948 and 1973 due to the shift of employment and hours from the farm to the nonfarm sector. The difference between the private economy and private business is that the former includes nonprofit institutions, households, and government enterprises, which combined represent about 8.5 percent of gross national product.

[8]The stock of R&D is equivalent to accumulated expenditures, depreciated each year at a rate of 10 percent. See Leo Sveikauskas, "The contribution of R&D to productivity growth," *Monthly Labor Review*, March 1986, pp. 16–20.

[9]Sveikauskas, "The contribution of R&D"; and Leo Sveikauskas, "Research and Development and Productivity Growth," paper presented at the annual meetings of the American Economic Association, New Orleans, LA, December 1986.

[10]William H. Waldorf, Kent Kunze, Larry Rosenblum, and Michael B. Tannen, "New Measures of the Contribution of Education and Experience to U.S. Productivity Growth," paper presented at the annual meetings of the American Economic Association, New Orleans, LA, December 1986.

[11]According to data from the Current Population Survey, in 1959, about 12 percent of the work force was between 18 and 24 years old and 50 percent of the total work force had graduated from high school. In 1969, 18- to 24-year-olds were about 17 percent of the work force and 64 percent of the total had a high school education or better. As of 1979, 18- to 24-year-olds were more than 19 percent of the work force and 75 percent of the work force had graduated from high school. By 1986, persons 18 to 24 had dropped to just over 16 percent of the work force, while 80 percent of the work force had graduated from high school.

[12]Waldorf, Kunze, Rosenblum, and Tannen, "New Measures of the Contribution of Education and Experience to U.S. Productivity Growth."

[13]These estimates are based on preliminary BLS research. See Edward Denison, *Trends in American Economic Growth, 1929–1982* (Washington, The Brookings Institution, 1985), and earlier studies by the same author, for use of the older estimates in measures.

APPENDIX: Recent revisions to multifactor productivity measures

This appendix describes two revisions made in the BLS multifactor productivity measures after they were introduced in 1983. One set of revisions involved the introduction of new output and capital input data for 1948 to 1984, developed using revised National Income and Product Accounts data released by the Bureau of Economic Analysis of the U.S. Department of Commerce in December 1985 and January 1986. The second revision is a methodological improvement in the technique for measuring capital inputs.

Revised data

In December 1985 and January 1986, the Bureau of Economic Analysis released revised national accounts data for the years 1929–84, which caused BLS to revise its computations of output and capital input for the entire period covered by its multifactor productivity measures, which begins in 1948. The revisions in the national accounts statistics were of two types, statistical changes and definitional and classification changes. The latter changes mainly affected components of gross national product—for example, output of general government—that BLS excludes from its measures of the output of the private business sector of the economy, and so need not be examined in a discussion of output revisions. Private business sector output is gross national product minus general government, government enterprises, nonprofit institutions, the household sector, owner-occupied housing, the statistical discrepancy, and the rest-of-the-world sector. (For further discussion, see *Trends in Multifactor Productivity*, Bulletin 2178 (Bureau of Labor Statistics, 1983), appendix F; and Jerome A. Mark, "Measuring single-factor and multifactor productivity," *Monthly Labor Review*, December 1986, pp. 3–11.)

The statistical changes in the national accounts affected the BLS measures of output as well as the measures of capital input. The output measures were most affected by four important statistical changes:

- Data from regularly used sources that appear less often than annually—for example, the 1977 input-output tables—were incorporated into the accounts.
- The Bureau of Economic Analysis made improved adjustments for misreporting on tax returns, sometimes misleadingly referred to as "underground economy adjustments." These adjustments were based on studies of the underreporting of income on tax returns and nonfiling of the returns.
- The base year for computation of the accounts was changed from 1972 to 1982. Hence, constant-dollar output series were computed using 1982, rather than 1972, prices.
- A price index for computers was introduced. Formerly, it had been assumed that computer prices had not changed over time. The new index showed an average annual decline in computer prices, after adjustment for quality change, of 14 percent per year between 1969 and 1984.

The BLS measures of capital services inputs are prepared using, among several data sources, Bureau of

Table A-1. Original and revised measures of multifactor productivity growth and related measures, private business, private nonfarm business, and manufacturing, 1948–84[1]

[In percent]

Sector	1948–73			1973–79			1979–84		
	Previous[2]	Revised[3]	Difference	Previous[2]	Revised[3]	Difference	Previous[2]	Revised[3]	Difference
Private business[4]									
Output	3.7	3.6	−0.1	2.7	2.5	−0.2	2.3	2.0	−0.3
Capital services	3.6	3.4	−.2	3.2	3.4	.2	2.9	3.6	.7
Combined inputs[5]	1.7	1.6	−.1	2.3	2.4	.1	1.5	1.8	.3
Multifactor productivity[6]	2.0	2.0	–	.4	.1	−.3	.8	.2	−.6
Private nonfarm business[4]									
Output	3.9	3.8	−.1	2.8	2.5	−.3	2.3	2.0	−.3
Capital services	3.6	3.5	−.1	3.3	3.7	.4	3.0	3.7	.7
Combined inputs[5]	2.1	2.1	–	2.5	2.6	.1	1.6	1.9	.3
Multifactor productivity[6]	1.7	1.7	–	.3	−.1	−.4	.7	.1	−.6
Manufacturing									
Output	4.0	3.9	−.1	2.0	1.9	−.1	1.3	1.4	.1
Capital services	3.4	3.7	.3	3.5	3.8	.3	2.0	2.5	.5
Combined inputs[5]	1.8	1.8	–	1.3	1.4	.1	−.5	−.4	.1
Multifactor productivity[6]	2.2	2.0	−.2	.7	.5	−.2	1.8	1.9	.1

[1] Average annual compound rates.

[2] Presented in "Multifactor Productivity Measures," USDL 85–405 (Bureau of Labor Statistics, Oct. 3, 1985).

[3] Presented in "Multifactor Productivity Measures, 1986," USDL 86–402 (Bureau of Labor Statistics, Oct. 2, 1986).

[4] Excludes government enterprises.

[5] Hours of all persons combined with capital services inputand weighted with labor and capital shares in the value of output.

[6] Output per unit of combined labor and capital input.

Economic Analysis data on real gross investment in depreciable assets and inventories. These real investment data also were revised in December 1985 and January 1986, along with other components of the national accounts. The four statistical changes mentioned in the discussion of output revisions, as well as two definitional and classification changes, all affected the series on real gross investment in depreciable assets. The two definitional and classification changes were the capitalization of replacement railroad track and the capitalization of major replacements to residential structures, such as roofs and heating systems.

The BLS measures of capital inputs were also affected by two other changes in procedures: (1) The Bureau of Economic Analysis adopted new—and usually longer—asset lives for several assets. The BLS uses these asset lives in developing measures of capital stocks from real gross investment data, utilizing the perpetual inventory method; and (2) for the first time, the Bureau of Economic Analysis prepared real gross investment data for 61 industries, essentially those industries at the two-digit level of the Standard Industrial Classification (SIC) system maintained by the U.S. Office of Management and Budget, in addition to investment data for major economic sectors. Using these disaggregated investment data, BLS prepared revised total productive capital stocks for each asset type for each major sector. These stocks were combined, using specially prepared weights, to provide measures of capital inputs for each major sector. The methods used in computation of productive capital stocks and in developing weights for each asset type were the same as those described in *Trends in Multifactor Productivity*, appendix C, with the single exception of the methodological improvement described in the next section of this appendix.

Finally, the Bureau of Economic Analysis revisions of late 1985 and early 1986 included revised data on incomes of capital and labor, and therefore led to changes in the shares of capital and labor in the value of output, the s_k and s_l terms discussed in connection with text equation 1. The revised data on capital income also affected the weights used to aggregate different productive capital stocks to produce a measure of aggregate capital services.

The Bureau of Economic Analysis described its revisions in several articles in its monthly publication, *Survey of Current Business*, in 1984 to 1986. Among these articles were Robert P. Parker, "Improved Adjustments for Misreporting of Tax Return Information Used to Estimate the National Income and Product Accounts, 1977," June 1984, pp. 17–25; John A. Gorman and others, "Fixed Private Capital in the United States," July 1985, pp. 36–57; "Revised Estimates of the National Income and Product Accounts of the United States, 1929–85: An Introduction," December 1985, pp. 1–33; and Roseann Cole and others, "Quality-Adjusted Price Indexes for Computer Processors and Selected Peripheral Equipment," January 1986, pp. 41–50.

A methodological improvement

The methodological improvement in the measurement of capital inputs affected the weights used to aggregate

productive capital stocks. These weights are calculated to reflect the importance of each type of capital stock in producing a flow of capital services. To compute these weights, an implicit rental price is calculated for each capital asset. One of the variables in the equation used to estimate the rental price is a capital appreciation term. In 1983, when the BLS measures were introduced, this capital appreciation term was the annual change in the price of the asset. The 1983 adoption by BLS of this "annual first difference" estimate accorded with the then-dominant view of specialists in productivity measurement.

Since 1983, BLS researchers, in collaboration with academic specialists, have determined that computation of capital appreciation using a 3-year moving average is superior to an annual first difference estimate. This conclusion follows careful examination of the theory of price expectations as well as empirical tests of the relative performance of alternative ways of measuring capital appreciation. This work is described in Michael J. Harper, Ernst R. Berndt, and David O. Wood, "Rates of Return and Capital Aggregation Using Alternative Rental Prices," Working Paper 170 (Bureau of Labor Statistics, July 1987).

The effects of the revisions and improvements described in this appendix are shown in table A-1. This table compares the BLS measures of output, capital services inputs, combined capital and labor inputs, and multifactor productivity before and after the revisions, as reflected in the data presented in the news releases of October 3, 1985, and October 2, 1986.