Trends in Multifactor Productivity, 1948-81

U.S. Department of Labor
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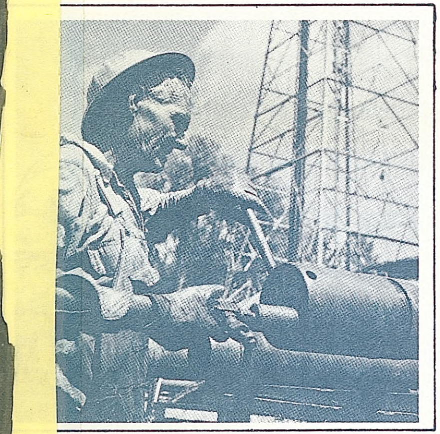
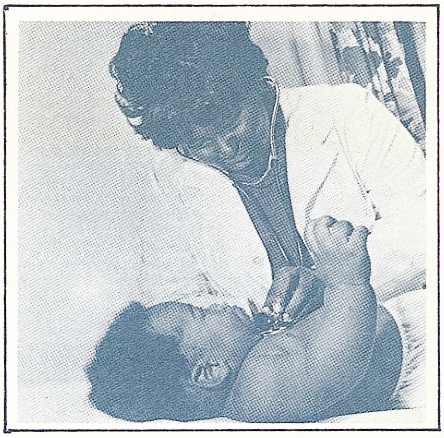


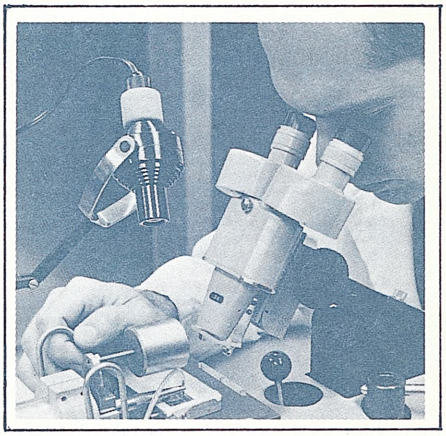

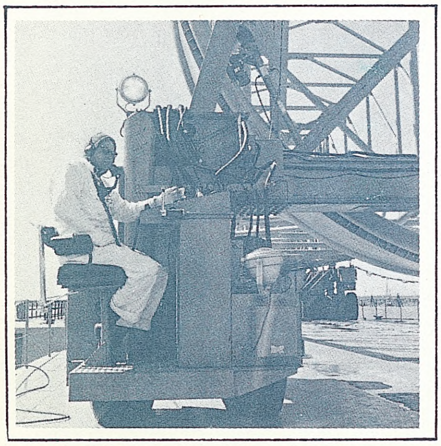

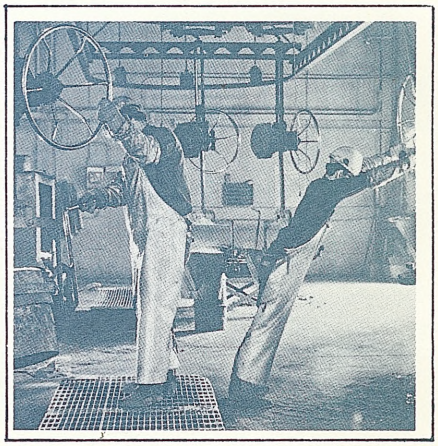

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Trends in Multifactor Productivity, 1948-81

U.S. Department of Labor
Raymond J. Donovan, Secretary

Bureau of Labor Statistics
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September 1983

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Preface

One of the principal functions of the Bureau of Labor Statistics is to inform policymakers on the utilization of the Nation's resources, particularly as this affects the well-being of U.S. workers. Thus an important part of the Bureau's work is the study of productivity, which is directly related to real income, price stability, employment, and the competitiveness of U.S. goods and services in world markets.

The major purpose of this bulletin is to present new BLS annual indexes of multifactor productivity for private business, private nonfarm business, and manufacturing for the period 1948 through 1981. These indexes incorporate capital in addition to labor inputs and are therefore more inclusive measures of productivity than the more familiar BLS measures of output per hour of all persons. The indexes, including revisions, will be published annually. The bulletin also presents for the first time BLS annual measures of output per unit of capital service inputs for the three sectors.

In addition, the bulletin presents revised, updated indexes of the BLS quarterly measures of output per hour of all persons in the business, nonfarm business, and manufacturing sectors for the period 1947 through 1982. It also includes revised annual indexes of real product per hour of all persons in the total private economy beginning in 1909. (Government enterprises are included in the productivity indexes for the business sectors but not in those for private business.) The bulletin also includes appendixes describing the methodology and basic data employed in constructing the BLS productivity measures. Previously, a comprehensive description of the methodology and data sources used to construct the output per hour measures was published in *Trends in Output per Man-hour in the Private Economy, 1909–1958*, Bulletin 1249 (1959).

The BLS measurement of multifactor productivity and output per unit of capital is in keeping with recommendations of the Panel to Review Productivity Statistics set up by the National Academy of Sciences and chaired by Professor Albert Rees. The panel's recommendations, published in 1979 by the National Academy of Sciences in *Measurement and Interpretation of Productivity*, were:

> "... that the Bureau of Labor Statistics experiment with combining labor and other inputs into alternative measures of multifactor productivity. (p.14)
>
> "... that government agencies make use of available estimates of real capital stocks to develop ratios of output per unit of capital in order to determine the savings that have been achieved over time in physical capital per unit of output." (p.11)

The new measures presented in this bulletin are the first of a series of measures of multifactor productivity that BLS will be producing. Future work will include multifactor productivity measures by major sector based on gross output and inputs of energy, materials, and purchased services as well as capital and labor services. In addition, BLS will be developing measures showing changes in the composition of the labor force, investment in research and development, capacity utilization, economies of scale, and resource allocation in order to see how these factors have influenced the growth of multifactor productivity.

This study was prepared by the Bureau's Office of Productivity and Technology under the direction of Jerome A. Mark, Associate Commissioner, and under the direct supervision of William H. Waldorf, Chief of the Division of Productivity Research, who also prepared the text. Kent Kunze prepared appendixes A and F; William Gullickson was responsible for appendix B; Michael Harper and Steven Rosenthal for appendix C; Lawrence J. Fulco for appendix D; and Kent Kunze and Leo Sveikauskas, appendix E. The staff of the Bureau of Economic Analysis, U.S. Department of Commerce, provided helpful comments in their review of the manuscript.

Contents

Contents—Continued

Contents—Continued

Tables—Continued *Page*

Summary of Findings

The American economy experienced a historically high rate of growth in productivity measured by output per hour during the quarter century 1948–73; however, the rate fell sharply in the following decade. There are a host of factors that could have caused these divergent trends: Changes in the amount of capital per worker, changes in technology, shifts in the composition of the work force, differences in effort per hour worked, changes in capacity utilization, increases in the cost of energy, and other factors.

This bulletin presents a recently constructed measure of productivity—multifactor productivity—which quantifies the effects of changes in the amount of capital per unit of labor (i.e., capital intensity), one of the most important sources of growth of output per hour of all persons. The new measure adds to existing BLS measures of productivity; it represents the Bureau's first step in trying to quantify the contributions of a number of major factors underlying the movements in productivity.

The index of multifactor productivity measures annual change in output per unit of combined labor and capital input. This is mathematically equivalent to subtracting the effects of annual rates of change in capital per hour from the annual rates of change in output per hour of all persons. Thus, the multifactor productivity measure differs from the familiar BLS measure of output per hour of all persons in that it excludes the effects of capital intensity. Comparing the two productivity series indicates how much of the growth or falloff in the traditional measure of output per hour was due to changes in capital per hour and how much was due to a combination of the other factors—i.e, changes in technology, shifts in the composition of the labor force, changes in capacity utilization, and so on.

In addition, the multifactor productivity index can be interpreted as one of a number of indicators of the economic progress of the U.S. economy because it shows the growth in output that has been obtained from a given amount of resources (capital and hours of labor), or, conversely, the reduction over time in the quantity of these resources used to produce a unit of output.

Private business sector

From 1948 to 1981, the period mainly covered in this bulletin, the growth of output per hour of all persons in the private business sector, which accounts for about 76 percent of gross national product, averaged 2.4 percent per year. During this period, capital inputs rose by 3.5 percent per year and hours of all persons by 0.9 percent, so that the rate of growth of capital services per hour (i.e., capital intensity) was 2.5 percent annually. This growth in capital per hour, when weighted by capital's share of total income, indicates that increased capital intensity contributed 0.9 percentage point—or roughly 40 percent—to the growth in output per hour. Multifactor productivity—the remainder—grew at an average annual rate of 1.5 percent. This rate of growth in multifactor productivity means that the U.S. economy produced about 65 percent more in 1981 than in 1948 from the same quantity of labor and capital resources.

Output per unit of capital services exhibited marked fluctuations between 1948 and 1981, but there was little or no apparent trend over the period as a whole. Thus, there was no measured saving in the amount of capital used to produce a unit of output over the more than three decades. In the latter part of the period, between 1973 and 1981, there was a decrease in output per unit of capital services, but this represented a change from the peak of one cycle to the trough of a later one, not a slowdown in the long-term trend.

The long-term average annual growth rate in output per hour, however, combines a high rate of growth (3.0 percent) between 1948 and 1973 with a much slackened one (0.8 percent) from 1973 to 1981. A small part of this falloff—0.3 percentage point—was the result of a slowdown in the annual rate of growth of capital per hour. The remainder—1.9 percentage points—came from a slowdown in multifactor productivity growth: Between 1973 and 1981, output per unit of combined capital and labor input rose by only 0.1 percent per year compared with 2.0 percent during 1948–73.

The slowdown in the rate of growth of capital per hour after 1973 reflects a decline in the rate of substitution of capital for labor. From 1948–73 to 1973–81, the average annual rate of growth of capital inputs in the private business sector decreased somewhat, whereas the growth rate of hours of all persons doubled. This decline in the rate of substitution of capital for labor after 1973 was largely associated with a change in relative factor prices: Historically, the price of capital has declined relative to the price of labor (average hourly compensation); during 1973–81, the average annual rate of decline in the price of capital relative to labor compensation was only half as great as in the earlier period, 1948–73.

Comparisons with earlier decades in this century for which reasonably comparable BLS data are available indicate that the average annual rate of growth in output per hour of all persons during 1948–73 was about the same as in the two decades 1918–28 and 1938–48. But the annual growth rate during 1973–81 was the lowest during any decade since 1909–18, when there was apparently no change in productivity.

Many factors have influenced the movements in the BLS measure of multifactor productivity. Judging from estimates made by BLS and private scholars, about 40 percent of the long-term growth rate can be explained; the rest remains unexplained. Of the 1.5 percent per year growth in multifactor productivity from 1948 to 1981, about 0.6 percentage point can be explained by (1) shifts of labor from the farm to the nonfarm sector (0.1 percentage point); (2) changes in the composition of the work force, mainly due to more education per worker (0.4 percentage point); (3) growth of research and development (R&D) expenditures (perhaps 0.2 percentage point); and (4) a reduction in hours worked relative to hours paid (−0.1 percentage point). Changes in utilization of physical capital appear to have had little or no effect on the long-term rate of growth of productivity.

These same underlying factors explain an even smaller fraction of the 1.9 percent per year falloff in multifactor productivity growth from 1948–73 to 1973–81. About 0.4 percentage point is accounted for by (1) the virtual end of the shift of labor from the farm to the nonfarm sector (0.2 percentage point); (2) a slowdown in the rate of growth of R&D (perhaps 0.1 percentage point); and (3) a decrease in hours worked relative to hours paid (0.1 percentage point). Changes in the composition of the work force took place at about the same rate before and after 1973 and therefore did not contribute to the slowdown. Measures of changes in the utilization of physical capital are not available for the private business sector as a whole; but judging from comparisons for manufacturing, changes in capacity utilization could have been an important factor contributing to the productivity falloff. However, even if this additional factor were included, the fraction of the falloff left unexplained would probably still be large.

Private nonfarm business sector

Although the numbers are different, the pattern of productivity growth was about the same in private nonfarm business as in private business as a whole. This is not surprising since the private nonfarm business sector constitutes about 95 percent of the private business sector. Between 1948 and 1981, output per hour of all persons in private nonfarm business grew at an average annual rate of 2.0 percent. Increases in capital input per hour contributed about 0.7 percent per year to the growth of output per hour. Multifactor productivity—output per unit of combined labor and capital input—grew at an average annual rate of 1.3 percent.

The annual rate of growth of output per hour of all persons dropped from 2.5 percent in 1948–73 to 0.6 percent during 1973–81, a slowdown of 1.9 percent per year. There was also a slowdown in the rate of growth of capital intensity, but this only contributed 0.2 percentage point to the falloff in output per hour. Multifactor productivity grew by 1.7 percent per year before 1973 but did not increase after that. That is, from 1973 to 1981, the growth in output came solely from increases in combined labor and capital inputs; in effect, the same quantity of resources produced the same amount of output in 1981 as it did almost a decade earlier.

Manufacturing sector

Productivity trends in manufacturing were similar to those in private business and private nonfarm business. But while the falloff in output per hour in the other two sectors was associated with slower rates of growth in capital inputs per hour after 1973, this was not the case in manufacturing.

From 1948 to 1981, output per hour of all persons in manufacturing increased by 2.6 percent per year; growth in capital intensity contributed about 0.8 percentage point; and multifactor productivity contributed the remainder, 1.8 percentage points. The growth in multifactor productivity in manufacturing was significantly faster than in private business and, particularly, private nonfarm business.

The average annual rate of growth in output per hour of all persons decreased from 2.9 percent during 1948–73 to 1.5 percent from 1973 to 1981. The growth of capital per hour accelerated between the two periods and, as a result, the falloff in output per hour was less than if there had been no rise in capital intensity. Consequently, the falloff in multifactor productivity was also greater than that for output per hour. Specifically, there was a 1.8 percent per year slowdown in the rate of growth of multifactor productivity after 1973.

Chapter I. Introduction

One of the major issues now facing the U.S. economy is the marked slowdown in productivity during the last decade. Between 1973 and 1982, the average annual rate of growth in output per hour of all persons in the business sector was only one-fourth the rate during the earlier postwar period, 1948 through 1973. The slowdown was pervasive: Each of the major sectors—manufacturing, farming, and nonfarm-nonmanufacturing—experienced lower rates of growth in output per person-hour during the last decade. BLS publishes annual indexes of productivity for 116 industries, and 80 percent of these showed productivity slowdowns after 1973.[1]

These slower growth rates are a major source of concern because productivity is important in determining national economic well-being. Productivity gains account for most of the increases in real compensation, so the slowdown means a retarded growth in the American standard of living. Chart 1 shows that, for the business sector, changes in hourly compensation adjusted for movements in consumer prices virtually paralleled those in output per hour of all persons, including the slowdown after 1973.

In addition, gains in productivity can contribute to price stability. Productivity increases help to offset the effects of increases in hourly compensation on unit labor cost which, in turn, are closely associated with changes in prices. By moderating price rises, productivity gains also contribute to the U.S. balance of trade by making the Nation's goods and services more competitive in world markets. BLS comparisons of productivity growth in 11 countries (the United States, Canada, 8 Western European countries, and Japan) show that, between 1960 and 1981, the average annual rate of growth in U.S. output per employee-hour in manufacturing was substantially below that of any of the other countries and only half as large as the combined average for the 10 foreign countries.[2] Like the United States, all of the other countries experienced a falloff in productivity growth in manufacturing after 1973 but, except for Canada, their post-1973 productivity growth rates remained substantially above that of the United States. The Canadian and U.S. annual productivity growth rates were virtually the same from 1973 to 1981.

Although the more familiar productivity measures relate output to hours of all persons engaged in a sector, they do not measure the specific contributions of labor, capital, or any other factor of production. Rather, they reflect the joint effects of many influences including changes in capital services, technology, level of output, utilization of capacity, the organization of production, managerial skill, and the composition and effort of the work force.

The new measure of multifactor productivity introduced in this bulletin relates output to inputs of both capital and labor and, therefore, includes more inputs than the BLS productivity index of output per hour of all persons. Since it incorporates capital inputs, the multifactor productivity measure is intended to reflect all of the same influences as the labor productivity measure discussed in the previous paragraph except for changes in capital services. The BLS is currently developing and reviewing measures of capacity utilization, composition of the labor force, investment in research and development, and other factors in order to determine their influence on movements in multifactor productivity.

The next chapter discusses the BLS quarterly indexes of output per hour of all persons and reviews trends and cyclical movements in these series since 1947, the first year for which the data are available. These quarterly measures are for the business sector, which includes government enterprises; the discussions in the succeeding chapters related to multifactor productivity are based on annual data and cover private business, which excludes government enterprises. Chapter III discusses the new BLS index of multifactor productivity, its changes, and how these relate to changes in output per hour of all persons and output per unit of capital input. Chapter IV reviews sources of change in multifactor productivity and their implications for the growth of productivity and the slowdown since 1973. The bulletin also includes six technical appendixes. Appendix A discusses the conceptual framework underlying the multifactor productivity measures; appendixes B, C, and D explain the methodology and basic data sources used in measuring output, capital inputs, and hours of all persons; appendix E presents a comparison of the results of using a Tornquist (changing weight) index versus a fixed weight index; and in appendix F, the new BLS multifactor productivity measures are compared with those constructed by other researchers.

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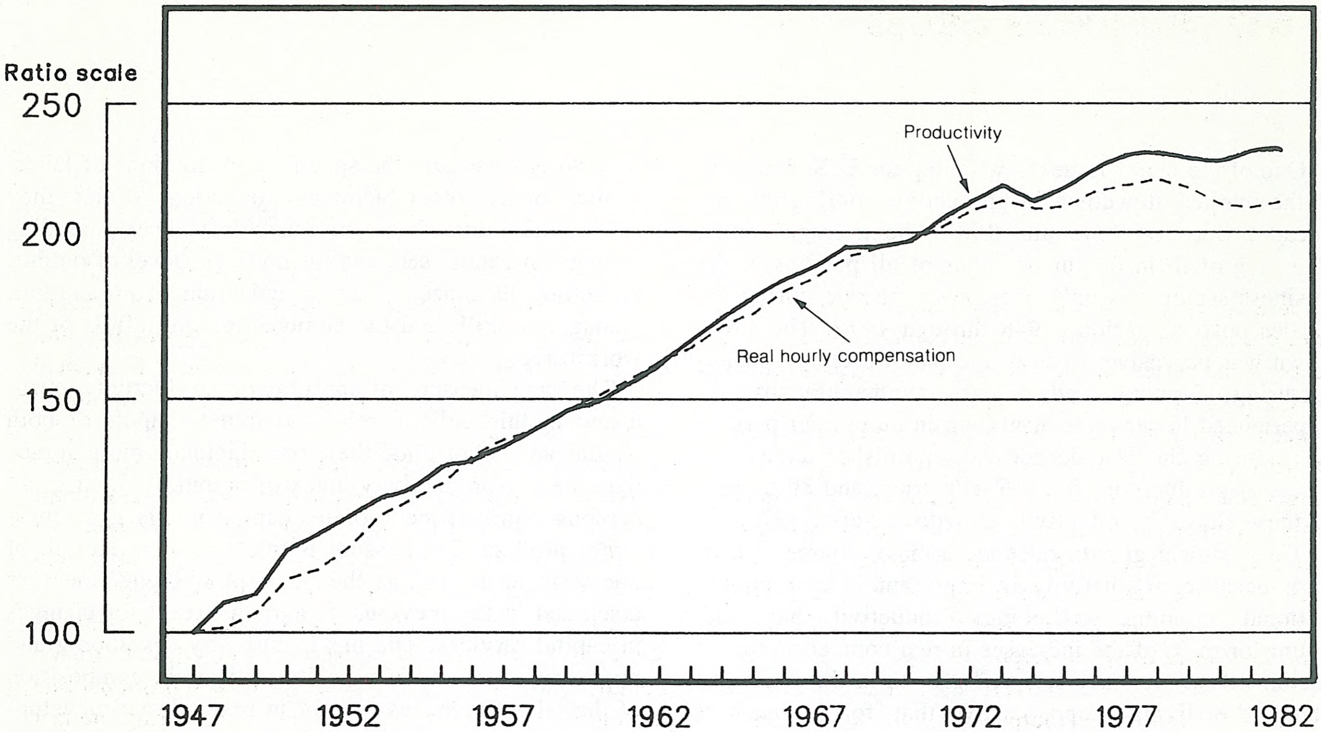
[1] *Productivity Measures for Selected Industries, 1954–81*, Bulletin 2155 (Bureau of Labor Statistics, December 1982).

[2] Patricia Capdevielle, Donato Alvarez, and Brian Cooper, "International Trends in Productivity and Labor Cost," *Monthly Labor Review*, December 1982, pp. 3–14. International comparisons are made in terms of output per employee-hour in manufacturing to achieve comparability of the series for each country.

Chart 1. Real hourly compensation and productivity in the business sector, 1947-82

(Index, 1947 = 100)



Chapter II. Output per Hour of All Persons in the Business Sector

There are many determinants of output per hour. Over time, changes in some of these result in cyclical movements in the series, while others have more gradual effects and give rise to trends. For example, rapid changes in output, coupled with lags in hiring or laying off workers, and changes in the utilization of the existing capital stock are likely to cause cyclical movements in output per hour. On the other hand, changes in such factors as capital per unit of labor, labor force composition, technology and its diffusion, and shifts of resources among sectors are likely to result in changes in the long-term trend of output per hour.

This chapter reviews movements since 1947 in the BLS quarterly indexes of output per hour of all persons in the business, nonfarm business, and manufacturing sectors and attempts to separate the trends from cyclical patterns. The trends are then used to date and gauge the extent of the productivity slowdown. Although cyclical movements in output per hour help to explain cyclical changes in unit labor costs, profits, and prices, which tend to retard both contractions and expansions during the business cycle, the relationships between output per hour and costs are not discussed in this bulletin.[1]

Cyclical movements in output per hour

Charts 2, 3, and 4 show quarterly changes in output per hour of all persons (seasonally adjusted) for the business, nonfarm business, and manufacturing sectors from the first quarter of 1947 (1947 I) through the fourth quarter of 1982 (1982 IV); the index numbers charted are given in table 3 at the end of this chapter. The shaded areas in the charts indicate periods of contraction in general business activity; the cyclical peaks and troughs are those designated by the National Bureau of Economic Research. Quarterly movements in the business sector are less clear than movements in the nonfarm subsector because of difficulties in seasonally adjusting output, employment, and average weekly hours in the farm sector for changes in weather and other conditions. Therefore, the analysis of cyclical movements focuses on both the business and nonfarm business sectors.

Output per hour in the nonfarm business sector rose consistently in all of the eight postwar expansions (chart 3) because output grew significantly faster than hours of all persons. The business sector exhibited the same pattern during the expansionary phases of the cycles.

During the contractions, however, the movements in aggregate output per hour were not consistent. In the nonfarm business sector, output per hour did not decline during the first five recessions, but it did during the last two. The percentage decreases in hours were greater than those in output during the first five recessions whereas, in the succeeding two contractions, hours declined relatively less than output. This was also the pattern in the business sector.

In sum, during each of the postwar cyclical expansions, hours of all persons showed significantly smaller relative increases than output, so that output per hour grew. However, during the contractions, hours sometimes fell relatively more and sometimes relatively less than output, so that labor productivity rose in some recessions but declined in others.[2] This suggests, among other things, that there is no simple, constant lag between hours and output at the aggregate level.

Trends in output per hour

The three charts showing quarterly movements in output per hour of all persons in business, nonfarm business, and manufacturing all indicate a definite slowdown in the rate of growth of productivity since early 1973, a shift now well established. There is, however, some question about whether the productivity slowdown actually started earlier, perhaps in 1965 or 1966. In or-

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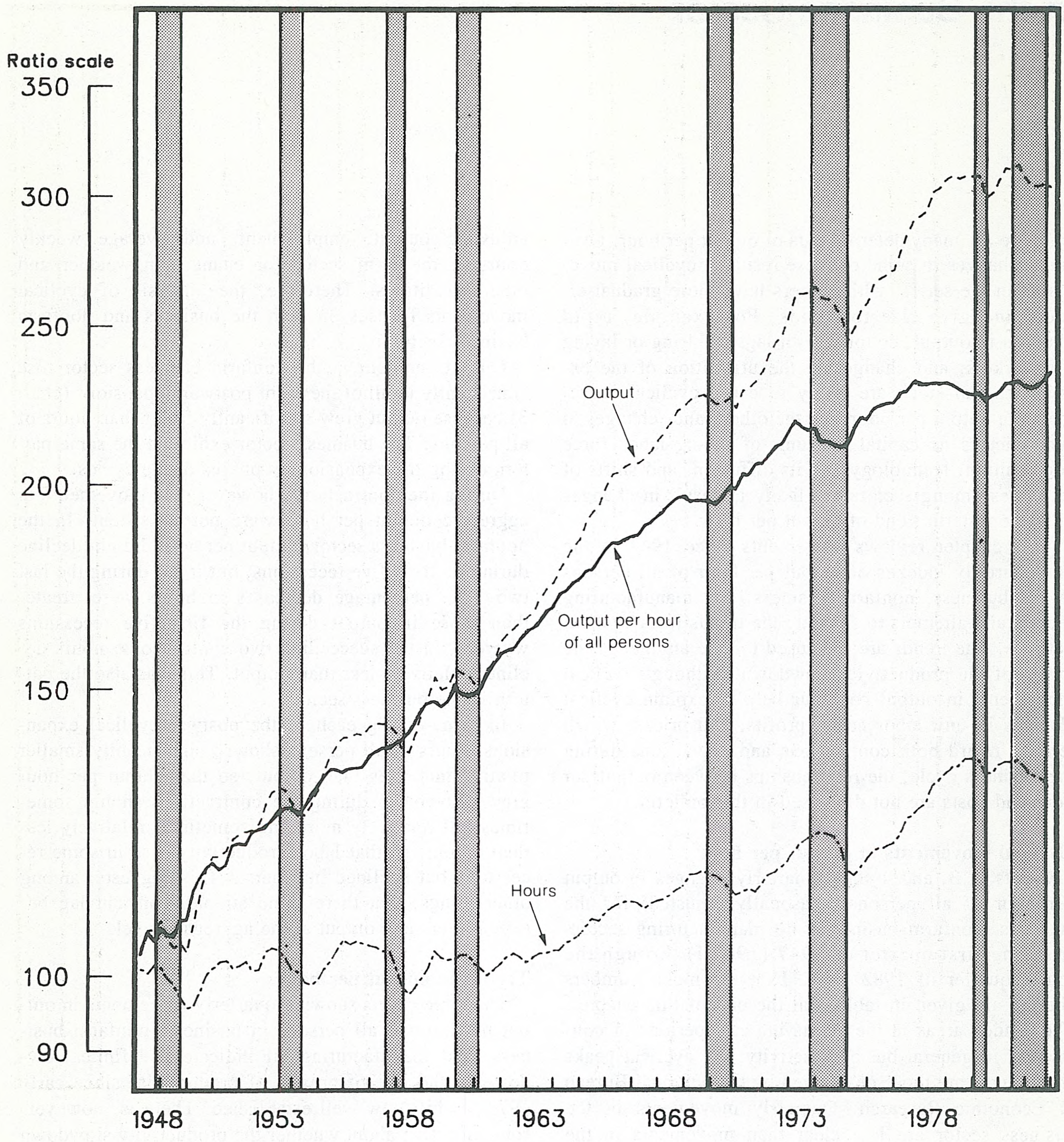
[1] See Wesley C. Mitchell, *Business Cycles and Their Causes* (Berkeley, University of California Press, 1941); and Geoffrey H. Moore and John Cullity, "Trends and Cycles in Productivity, Unit Costs, and Prices: An International Perspective," paper presented at the Conference on International Comparisons of Productivity and *Causes of the Slowdown* held by the American Enterprise Institute, Washington, Sept. 30, 1982.

[2] These results are somewhat at variance with those reported by Thor Hultgren based on industry data. He found that "manhours in the aggregate usually do not rise and do not fall by as great a percentage as output." See Thor Hultgren, "Changes in Labor Cost During Cycles in Production and Business," Occasional Paper 74 (New York, National Bureau of Economic Research, 1960), p. 8. The difference between Hultgren's conclusions and those offered here, which are based on broad aggregates, may be due in part to changes in the product mix during cyclical contractions.

Chart 2. Business sector: Output per hour, output, and hours, quarterly, 1948-82

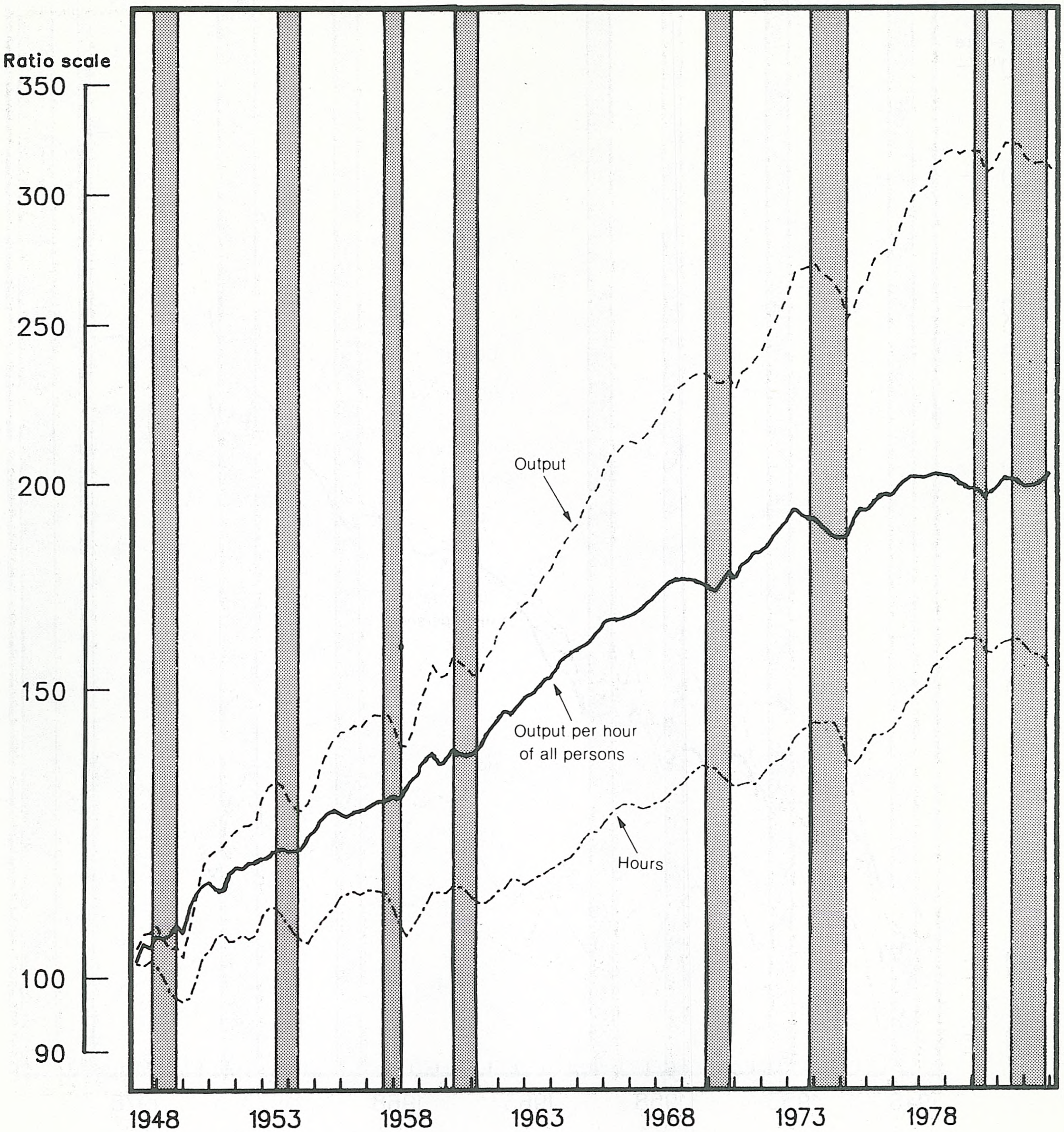
(Index, 1947 = 100)



NOTE: Shaded areas indicate recessions.

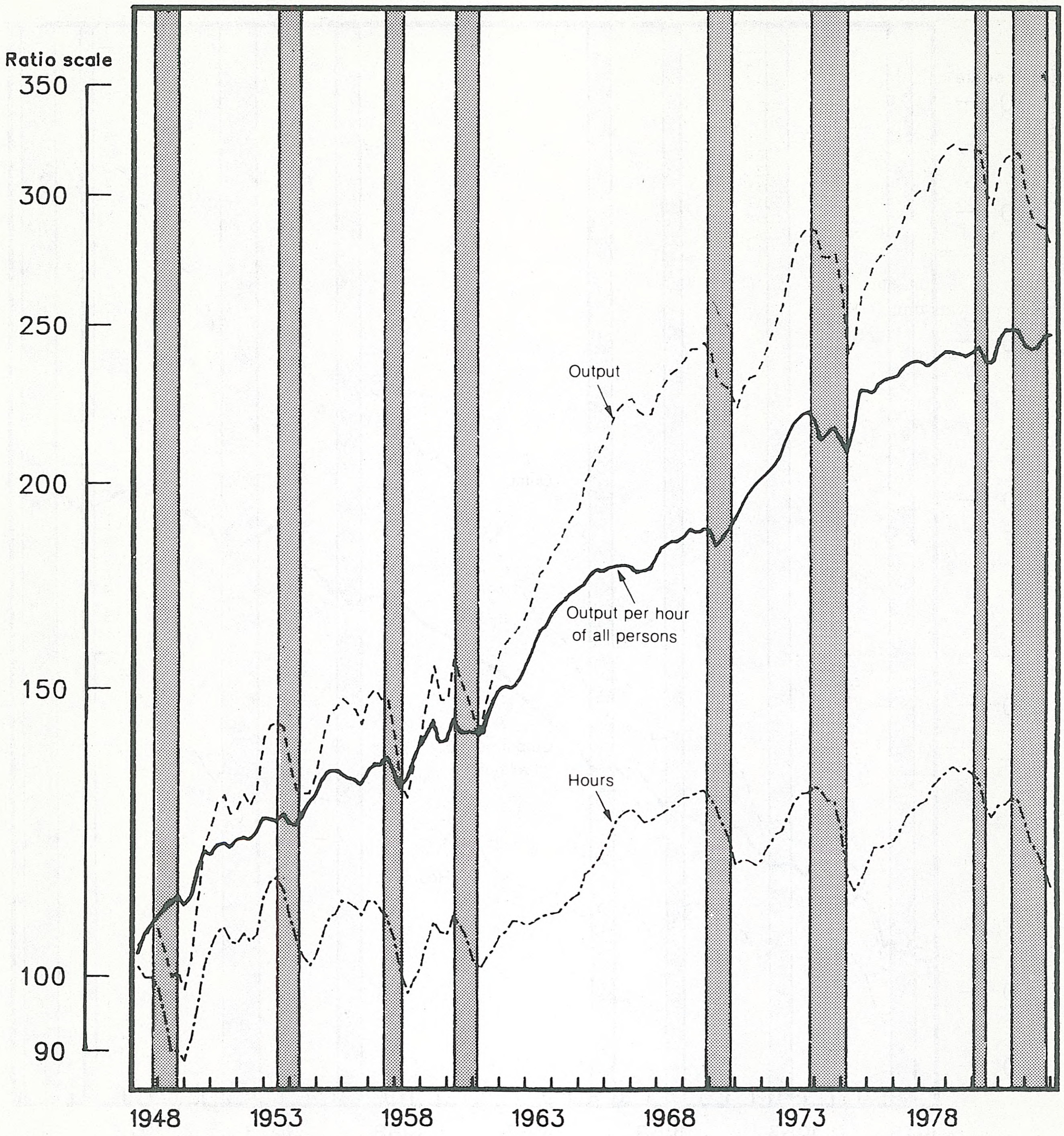
Chart 3. Nonfarm business sector: Output per hour, output, and hours, quarterly, 1948-82

(Index, 1947 = 100)



NOTE: Shaded areas indicate recessions.

Chart 4. Manufacturing sector: Output per hour, output, and hours, quarterly, 1948-82
(Index, 1947 = 100)



NOTE: Shaded areas indicate recessions.

der to see this, long-term trends have to be separated from cyclical and random fluctuations.

One method of highlighting the long-term trends is to compare rates of growth in output per hour of all persons at peaks of business activity. Since these are at the same stage of the business cycle, there is a presumption that utilization of capital and labor is also "roughly" the same. These peak-to-peak comparisons for the business and nonfarm business sectors show that, although the annual growth rate in productivity differed among periods, the only clearly evident slowdown occurred after 1973 (table 1).[3] The productivity growth rate in the business sector during the initial period, 1948 IV—1953 III, was unusually high (3.7 percent) and reflects a sharp rise in farming. There was a productivity slowdown in the subsequent period, 1953 III—1957 III, but this was not as large or as prolonged as the one after 1973.

In sum, the peak-to-peak comparisons of growth rates in output per hour of all persons based on quarterly data confirm that the slowdown began in early 1973; they do not reveal any falloff before then.[4] For this reason, the analyses of the slowdown in this bulletin are based only on a comparison of the periods before and after 1973.

Table 1. Rates of growth in output per hour of all persons between business cycle peaks in the business and nonfarm business sectors, 1948 IV to 1981 III

(Percent per year, compounded)

Period[1]	Business	Nonfarm business
1948 IV–1953 III	3.7	2.6
1953 III–1957 III	2.1	1.4
1957 III–1960 II	2.8	2.8
1960 II–1969 IV	2.9	2.5
1969 IV–1973 IV	2.6	2.4
1973 IV–1980 I	0.8	0.6
1980 I–1981 III	1.1	0.9

[1]Cyclical peaks are those designated by the National Bureau of Economic Research.

SOURCE: Table 3.

Table 2. Rates of growth in output per hour of all persons, output, and hours by major sector, 1948–81

(Percent per year, compounded)

Sector and measure	1948–81 (1)	1948–73 (2)	1973–81 (3)	Slowdown (3)−(2)
Business:[1]				
Output per hour	2.4	2.9	0.8	−2.1
Output	3.3	3.7	2.2	−1.5
Hours	0.9	0.7	1.4	0.7
Nonfarm business:[1]				
Output per hour	2.0	2.5	0.6	−1.9
Output	3.4	3.8	2.1	−1.7
Hours	1.4	1.3	1.5	0.2
Manufacturing:				
Output per hour	2.6	2.9	1.5	−1.4
Output	3.3	4.0	1.2	−2.8
Hours	0.7	1.1	−0.2	−1.3

[1]Includes government enterprises.

SOURCE: Table 4.

Post-1948 growth rates

During the three decades from 1948 to 1981, output per hour of all persons in the business sector of the economy grew at an average annual rate of 2.4 percent. (Table 2 presents a summary of the quarterly and annual data provided in table 3.) This was significantly higher than the rate in nonfarm business (2.0 percent) because of a high rate of growth of output per hour in farming. During the same three decades, the annual rate of growth in output per hour in manufacturing (2.6 percent) was slightly higher than in the business sector but substantially higher than in nonfarm business, apparently because of slower rates of growth of productivity in nonfarm-nonmanufacturing activities. Coincidentally, output grew at virtually the same annual rate in the three sectors (about 3.3 percent) during the three decades. The highest rate of growth in hours of all persons occurred in nonfarm business, specifically in nonfarm-nonmanufacturing.

[3]Peter Clark also used peak-to-peak growth rates in order to date the slowdown in labor productivity up to 1973 II, the latest period for which the data were then available. For the period after that, he developed an econometric model based on a lagged response of labor inputs (hours) to output. His model assumes that the structure of the lag is constant throughout the postwar period but, as earlier analysis in the text shows, there was no constant lag during business contractions. Also, about one-half of the slowdown (0.8 percent per year) that Clark found for 1965 II—1973 II compared with 1955 IV—1965 II for the business and nonfarm business sectors based on earlier BLS data has "disappeared" in subsequent statistical revisions. See Peter K. Clark, "Capital Formation and the Recent Productivity Slowdown," *Journal of Finance*, June 1978, pp. 1965–75.

[4]In addition, comparison of average annual rates of growth in the index itself, measured between peaks, indicates that, to the extent that there was a slowdown in the series prior to 1973, it was small. The quarters in which the output per hour series peaked were 1950 IV, 1966 II, and 1973 II. The average yearly growth rate in the business sector declined from 2.9 percent in 1950 IV—1966 II to 2.6 percent in 1966 II—1973 II, only 0.3 percentage point; for the nonfarm business sector the decline in the rate of growth between the same two periods was from 2.4 percent to 2.2 percent, only 0.2 percentage point. The results are virtually the same based on growth rates computed between 3-quarter averages of output per hour centered on the 3 peak quarters. These growth rate differentials are all well within the range of variation of those shown in table 1 for the periods before 1973 IV. The comparisons in this footnote begin with 1950 IV because the sharp rise in productivity prior to that quarter reflects the sharp rise in farming during the Korean War (see charts 2 and 3). Other analysts, relying on annual data, have placed the beginning of the productivity slowdown in the mid-1960's.

Comparisons of the annual growth rates in the two periods 1948–73 and 1973–81 show the dimensions of the productivity slowdown during the last decade. In the business sector, output per hour of all persons grew at a yearly rate of only 0.8 percent from 1973 to 1981, slightly more than one-fourth the 2.9 percent growth rate between 1948 and 1973. This reflects a sharp drop in the annual rate of growth of output (1.5 percent) coupled with a significant increase in the rate of growth of hours (0.7 percent). Part of the productivity slowdown resulted from shifts of output and employment from industries with higher to those with lower levels of output per hour.

Nonfarm business experienced a similar slowdown in productivity after 1973. The annual rate of growth of output per hour fell from 2.5 percent during 1948–73 to 0.6 percent during 1973–81. This reflects a somewhat larger drop in the rate of growth of output (1.7 percent) and a significantly smaller slowing of the rate of growth in hours than in the business sector. The annual rate of growth in hours in nonfarm business (1.3 percent) during 1948–73 was substantially larger than in the business sector (0.7 percent) because of the large shift of workers from farm to nonfarm activities. The growth rates for hours in the two sectors were about the same during 1973–81, which indicates that the major shift of labor out of farming was essentially completed by 1973.[5]

In manufacturing, the average annual growth rate in output per hour was 1.5 percent during 1973–81 compared with 2.9 percent in 1948–73, a falloff of 1.4 percent per year. In contrast to the other two sectors, the slowdown in manufacturing reflects decreases in the annual growth rates of both output (2.8 percent) and hours (1.3 percent). In fact, hours declined by 0.2 percent per year from 1973 to 1981 whereas they grew by 1.1 percent in the earlier period, 1948–73.

The long term: 1909–81

BLS also maintains an annual series on output per hour of all persons in the private economy for the period 1909–47.[6] This series was linked to the BLS measure of output per hour of all persons in the business sector in order to review long-term movements in productivity (chart 5 and table 4). This makes it possible to broadly judge U.S. long-term progress in productivity and to see whether there was a similar slowdown prior to 1948.

In 1981, output per hour of the average American worker was about 4½ times as much as it was in 1909. This averages out to a long-term yearly rate of growth of 2.5 percent. The annual rates of growth varied substantially among the seven decades. The differential movements largely reflected major events such as the two World Wars, the Great Depression, and various recessions.

Comparisons of the pre- and post-1948 experience show that the average annual rate of growth in output per hour during 1948–73 was about the same as during the two decades 1918–28 and 1938–48. Two earlier periods also were marked by low productivity growth: 1909–18, when there was virtually no change in output per hour, and 1929–38, when productivity increased only 1.6 percent per year. However, these two periods of little or no productivity growth differ from the 1973–81 experience: The post-1973 productivity falloff was associated with a 3.0 percent annual rate of growth in output whereas in 1909–18 output grew by only 1.5 percent per year, and in 1929–38 there was virtually no growth in output.

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[5]The proportion of all persons in the business sector engaged in farming was 15.5 percent in 1948, 7.3 percent in 1965, 4.7 percent in 1973, and 3.5 percent in 1981. Since output per hour is lower in the farm than in the nonfarm sector, the smaller decrease in the percentage after 1965 compared with the period from 1948 to 1965 partially accounts for the small slowdown in labor productivity between 1965 and 1973 noted earlier.

[6]The private economy is defined as gross national product excluding general government. As measured in the National Income and Product Accounts, the output of the business sector accounts for between 85 and 90 percent of output of the private economy. See appendix B for a detailed discussion of the relationship between gross national product and business output and some of the problems in using the broader concept for productivity measurement.

Chart 5. Output per hour, 1909-82

(Index, 1909 = 100)

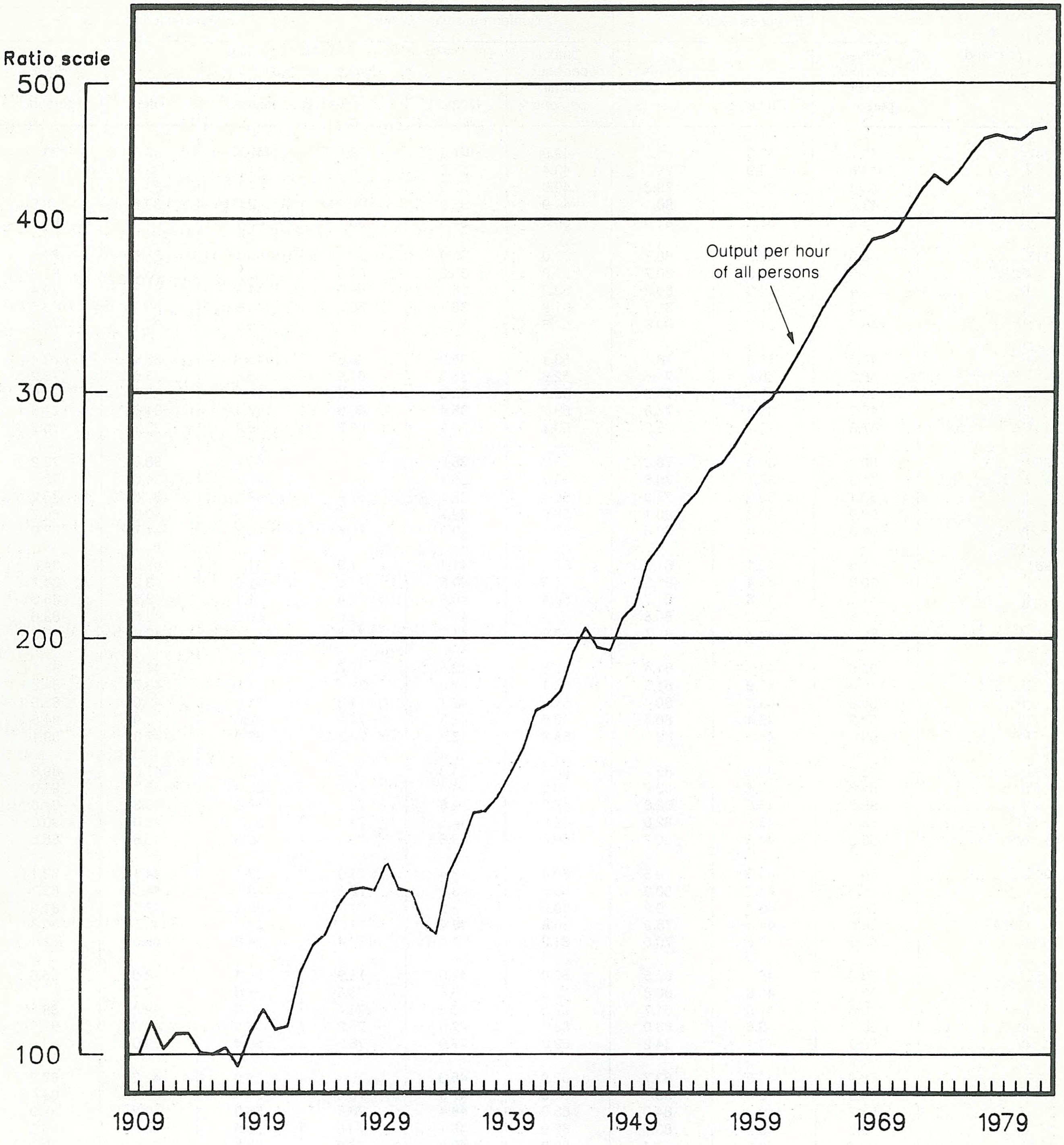


Table 3. Output per hour, output, and hours of all persons by major sector, annual and quarterly, 1947–82
(Index, 1977=100)

Year and quarter	Business sector			Nonfarm business sector			Manufacturing sector		
	Output per hour of all persons	Output	Hours of all persons	Output per hour of all persons	Output	Hours of all persons	Output per hour of all persons	Output	Hours of all persons
1947	43.7	35.0	80.2	49.9	34.0	68.1	42.4	33.9	79.9
I	43.6	34.9	80.0	49.4	33.6	68.0	41.6	33.5	80.5
II	43.8	34.9	79.6	49.9	33.9	67.9	42.2	33.7	79.9
III	43.6	34.9	80.1	49.9	33.9	67.9	42.6	33.6	78.8
IV	43.8	35.5	81.0	50.3	34.5	68.7	43.1	34.7	80.4
1948	46.0	37.2	80.7	52.0	36.0	69.2	45.1	35.8	79.4
I	45.0	36.3	80.7	51.0	35.3	69.3	43.7	35.2	80.6
II	46.4	37.3	80.2	52.2	36.1	69.0	44.9	35.7	79.4
III	45.9	37.2	81.1	51.9	36.1	69.6	45.6	36.2	79.5
IV	46.7	37.7	80.8	52.8	36.5	69.1	46.0	36.1	78.3
1949	46.7	36.5	78.1	53.1	35.3	66.6	46.9	33.9	72.4
I	46.3	36.8	79.6	52.6	35.8	67.9	46.5	35.0	75.2
II	46.1	36.4	78.8	52.9	35.3	66.7	46.9	33.7	71.9
III	47.2	36.6	77.5	53.7	35.4	66.0	47.4	34.0	71.6
IV	47.3	36.1	76.3	53.1	34.9	65.7	46.8	33.1	70.7
1950	50.4	39.8	78.9	56.3	38.6	68.7	49.4	38.6	78.2
I	49.3	37.7	76.5	55.1	36.4	66.1	47.5	34.6	72.9
II	50.1	39.2	78.3	56.1	38.1	67.8	49.2	37.5	76.2
III	50.9	40.8	80.1	56.8	39.7	70.0	50.5	40.8	80.7
IV	51.3	41.4	80.8	57.1	40.3	70.6	50.3	41.7	82.9
1951	51.8	42.1	81.3	57.2	41.1	71.9	51.1	43.0	84.2
I	50.8	41.4	81.5	56.5	40.6	71.9	51.0	43.2	84.7
II	51.1	41.8	81.7	56.4	40.9	72.4	51.1	43.6	85.3
III	52.6	42.4	80.8	57.8	41.4	71.6	50.8	42.5	83.6
IV	52.7	42.7	81.1	58.3	41.7	71.6	51.4	42.8	83.3
1952	53.5	43.5	81.4	58.6	42.5	72.6	52.0	44.5	85.4
I	52.6	42.9	81.6	58.1	42.0	72.2	51.6	43.7	84.6
II	53.6	43.1	80.4	58.6	42.1	71.8	51.4	43.0	83.6
III	53.8	43.4	80.6	58.6	42.3	72.2	52.0	43.9	84.5
IV	53.9	44.6	82.7	58.9	43.7	74.3	53.1	47.3	89.1
1953	55.2	45.4	82.2	59.5	44.3	74.5	52.9	47.5	89.8
I	54.6	45.4	83.2	59.2	44.4	75.0	52.9	48.1	91.0
II	55.3	45.8	82.8	59.6	44.8	75.2	52.8	48.3	91.6
III	55.5	45.5	82.0	59.8	44.5	74.3	53.3	48.0	90.0
IV	55.5	44.8	80.7	59.6	43.6	73.3	52.6	45.6	86.6
1954	56.1	44.6	79.5	60.4	43.4	71.9	53.7	44.1	82.1
I	55.0	44.2	80.3	59.6	43.1	72.3	52.5	44.0	83.7
II	55.5	43.9	79.2	59.9	42.9	71.7	53.4	43.8	81.9
III	56.5	44.6	78.9	60.8	43.4	71.3	54.2	43.7	80.8
IV	57.3	45.5	79.5	61.2	44.4	72.4	54.8	45.0	82.1
1955	58.3	48.1	82.5	62.8	47.0	75.9	56.4	48.9	86.6
I	58.0	46.8	80.8	62.2	45.8	73.5	56.0	47.2	84.3
II	58.6	47.9	81.7	62.9	46.8	74.4	56.6	49.0	86.6
III	58.5	48.6	83.0	63.2	47.5	75.2	56.6	49.2	87.0
IV	58.3	49.1	84.2	62.8	47.9	76.3	56.4	50.0	88.6
1956	58.9	49.3	83.7	62.9	48.3	76.8	56.0	49.2	87.9
I	58.6	49.0	83.7	62.5	47.9	76.6	56.0	49.5	88.4
II	58.7	49.3	84.0	63.0	48.4	76.8	56.0	49.2	87.9
III	58.7	49.2	83.7	62.9	48.1	76.5	55.5	48.2	86.8
IV	59.7	49.8	83.4	63.3	48.8	77.0	56.5	50.0	88.6
1957	60.4	49.8	82.5	64.0	48.9	76.4	57.1	49.5	86.5
I	60.1	50.0	83.3	63.7	49.1	77.0	57.2	50.6	88.5
II	60.3	50.0	82.8	63.8	49.0	76.8	57.1	49.9	87.4
III	60.3	50.0	82.9	64.1	49.1	76.6	57.7	49.9	86.4
IV	60.8	49.3	81.1	64.4	48.4	75.1	56.5	47.4	83.8
1958	62.3	49.0	78.8	65.5	48.0	73.2	56.9	45.2	79.4
I	61.1	48.1	78.8	64.1	47.0	73.3	55.3	44.3	80.1
II	61.7	48.0	77.8	65.2	47.0	72.1	56.0	43.5	77.6
III	62.6	49.2	78.6	65.8	48.1	73.1	57.5	45.5	79.1
IV	63.8	50.9	79.8	67.1	49.8	74.2	58.9	47.5	80.7

Table 3. Output per hour, output, and hours of all persons by major sector, annual and quarterly, 1947–82—Continued

(Index, 1977=100)

Year and quarter	Business sector			Nonfarm business sector			Manufacturing sector		
	Output per hour of all persons	Output	Hours of all persons	Output per hour of all persons	Output	Hours of all persons	Output per hour of all persons	Output	Hours of all persons
1959	64.3	52.6	81.9	67.7	51.8	76.5	59.6	50.5	84.7
I	64.3	52.0	80.9	67.6	51.0	75.5	59.7	49.9	83.6
II	64.4	53.4	82.8	68.4	52.6	76.9	60.8	52.3	86.0
III	63.9	52.4	82.0	67.3	51.7	76.7	58.9	49.9	84.7
IV	64.4	52.7	81.8	67.6	51.8	76.7	59.1	49.8	84.4
1960	65.2	53.5	82.0	68.3	52.5	77.0	60.0	50.7	84.4
I	65.9	54.0	81.8	68.7	53.2	77.4	60.9	52.8	86.7
II	65.1	53.7	82.4	68.2	52.8	77.3	59.8	51.1	85.5
III	64.8	53.4	82.4	68.1	52.4	76.9	59.6	50.1	83.9
IV	64.9	52.8	81.4	68.1	51.8	76.1	59.7	48.6	81.4
1961	67.3	54.4	80.8	70.3	53.5	76.1	61.6	50.7	82.3
I	65.5	52.9	80.8	68.7	51.9	75.6	59.5	47.8	80.4
II	67.4	53.9	80.0	70.1	53.0	75.6	61.1	49.9	81.7
III	67.8	54.6	80.6	70.7	53.8	76.1	62.5	51.6	82.6
IV	68.9	56.0	81.3	71.8	55.2	76.9	63.4	53.4	84.2
1962	69.9	57.4	82.1	72.8	56.6	77.8	64.3	55.1	85.6
I	69.1	56.7	82.1	72.4	55.9	77.2	63.8	54.1	84.8
II	69.3	57.2	82.5	72.0	56.3	78.2	63.5	54.7	86.1
III	70.3	57.7	82.1	72.9	56.9	78.0	64.3	55.3	86.0
IV	71.2	58.0	81.5	73.9	57.3	77.5	65.6	56.1	85.6
1963	72.5	59.9	82.6	75.1	59.1	78.7	68.9	59.6	86.5
I	71.4	58.6	82.1	74.1	57.8	78.0	67.0	57.6	85.9
II	72.2	59.6	82.6	74.9	58.8	78.5	68.8	59.5	86.5
III	73.1	60.4	82.6	75.7	59.6	78.7	69.3	60.1	86.8
IV	73.5	61.0	82.9	76.0	60.2	79.2	70.4	61.3	87.0
1964	75.6	63.5	83.9	78.1	62.8	80.5	72.3	63.9	88.4
I	75.0	62.1	82.9	77.2	61.5	79.7	71.3	62.2	87.2
II	75.2	63.0	83.8	77.8	62.4	80.2	72.1	63.5	88.1
III	76.1	64.0	84.1	78.7	63.3	80.5	72.6	64.5	88.9
IV	76.5	64.7	84.7	78.7	64.1	81.4	73.0	65.3	89.4
1965	78.3	67.8	86.6	80.5	67.2	83.5	74.5	69.8	93.6
I	77.4	66.3	85.7	79.4	65.6	82.6	73.7	67.8	92.0
II	77.6	67.3	86.7	80.0	66.7	83.4	74.5	69.2	92.8
III	78.7	68.0	86.4	80.7	67.4	83.4	75.1	70.5	93.9
IV	79.7	69.6	87.4	81.9	69.1	84.4	74.8	71.6	95.7
1966	80.7	71.5	88.6	82.5	71.2	86.3	75.3	75.1	99.8
I	80.5	71.0	88.1	82.4	70.5	85.5	75.3	73.7	97.8
II	80.4	71.2	88.6	82.2	70.8	86.2	75.4	75.1	99.6
III	80.8	71.8	88.8	82.5	71.6	86.7	75.5	75.8	100.4
IV	81.2	72.1	88.8	82.9	71.9	86.7	75.4	76.1	101.0
1967	82.5	73.1	88.6	84.0	72.7	86.5	75.3	75.0	99.6
I	81.3	72.1	88.6	82.9	71.7	86.5	74.7	74.8	100.1
II	82.5	72.6	88.0	83.9	72.3	86.1	75.0	74.2	99.0
III	82.8	73.4	88.6	84.4	73.0	86.5	75.1	74.5	99.2
IV	83.6	74.4	89.0	85.1	73.9	86.9	76.5	76.4	99.9
1968	85.3	76.8	90.1	86.8	76.6	88.2	78.0	79.1	101.4
I	84.4	75.3	89.2	86.0	75.0	87.2	77.5	77.7	100.4
II	85.0	76.4	89.8	86.7	76.2	87.9	78.1	78.9	101.0
III	85.8	77.6	90.4	87.2	77.3	88.7	78.0	79.4	101.8
IV	85.9	78.1	91.0	87.2	77.8	89.2	78.4	80.3	102.4
1969	85.5	79.0	92.5	86.5	78.8	91.1	79.3	81.7	103.1
I	85.3	78.8	92.4	87.1	78.5	90.2	79.5	81.6	102.7
II	85.5	79.1	92.5	86.7	78.9	91.0	79.1	81.7	103.3
III	85.5	79.4	92.9	86.4	79.1	91.6	79.5	82.3	103.6
IV	85.3	78.8	92.4	86.2	78.7	91.3	79.3	81.3	102.6
1970	86.2	78.4	91.0	86.8	78.0	89.8	79.1	77.0	97.3
I	85.0	78.3	92.2	85.5	78.0	91.2	77.6	78.4	101.0
II	85.8	78.4	91.4	86.6	78.0	90.1	78.6	77.5	98.6
III	87.3	79.0	90.5	88.0	78.7	89.4	79.6	77.0	96.7
IV	86.8	77.9	89.7	87.1	77.3	88.8	80.6	75.1	93.2

Table 3. Output per hour, output, and hours of all persons by major sector, annual and quarterly, 1947–82—Continued

(Index, 1977=100)

Year and quarter	Business sector			Nonfarm business sector			Manufacturing sector		
	Output per hour of all persons	Output	Hours of all persons	Output per hour of all persons	Output	Hours of all persons	Output per hour of all persons	Output	Hours of all persons
1971	89.2	80.7	90.5	89.7	80.3	89.5	83.9	78.7	93.7
I	88.7	79.9	90.0	88.9	79.2	89.1	82.3	77.3	93.9
II	88.6	80.2	90.5	89.2	79.7	89.4	83.6	78.4	93.8
III	89.9	81.0	90.0	90.4	80.6	89.1	84.5	78.7	93.1
IV	90.0	82.0	91.1	90.4	81.6	90.2	85.5	80.3	94.0
1972	92.4	86.1	93.2	93.0	85.8	92.3	88.2	86.2	97.8
I	91.0	84.0	92.3	91.4	83.4	91.3	86.1	82.5	95.8
II	92.2	85.4	92.7	92.4	85.0	91.9	87.0	84.7	97.4
III	92.6	86.4	93.3	93.6	86.5	92.4	88.7	86.9	97.9
IV	94.0	88.6	94.3	94.7	88.5	93.5	90.9	90.9	100.0
1973	94.7	91.8	96.8	95.3	91.7	96.2	93.0	95.9	103.2
I	95.6	91.5	95.6	96.1	91.3	95.0	92.3	94.3	102.1
II	94.8	91.5	96.5	95.3	91.5	96.0	93.3	96.2	103.1
III	94.3	91.6	97.2	94.9	91.8	96.7	93.8	96.8	103.2
IV	94.5	92.4	97.7	94.9	92.2	97.2	92.5	96.4	104.1
1974	92.5	89.9	97.3	92.9	89.8	96.7	90.8	91.9	101.2
I	92.8	90.9	98.0	93.8	91.0	97.0	90.0	92.9	103.2
II	92.8	90.7	97.8	93.0	90.5	97.2	91.0	92.8	102.0
III	92.2	89.8	97.4	92.4	89.7	97.1	91.7	93.3	101.8
IV	92.0	88.3	96.0	92.3	88.1	95.4	90.3	88.5	98.1
1975	94.5	88.2	93.3	94.7	89.8	92.7	93.4	85.4	91.4
I	92.1	85.7	93.0	92.4	85.4	92.4	88.4	80.9	91.5
II	94.6	87.2	92.1	94.7	86.7	91.5	92.0	82.7	89.8
III	96.0	89.5	93.2	96.2	89.0	92.5	96.6	88.1	91.2
IV	95.7	90.3	94.4	95.8	90.0	94.0	96.4	89.9	93.2
1976	97.6	93.8	96.0	97.8	93.7	95.8	97.5	93.6	95.9
I	97.2	92.9	95.6	97.1	92.7	95.4	96.2	92.1	95.7
II	97.6	93.5	95.8	98.0	93.5	95.4	97.4	93.2	95.7
III	97.9	94.0	96.1	98.2	94.1	95.8	97.9	94.2	96.1
IV	98.0	94.6	96.6	97.9	94.5	96.5	98.3	94.9	96.5
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
I	99.4	97.0	97.6	99.3	97.0	97.7	99.0	96.9	97.9
II	99.6	99.5	99.9	99.9	99.6	99.7	99.9	99.8	99.8
III	100.9	101.5	100.6	100.6	101.4	100.8	100.4	101.2	100.8
IV	100.5	102.0	101.5	100.4	102.0	101.6	100.5	102.1	101.6
1978	100.6	105.5	104.9	100.6	105.7	105.0	100.8	105.3	104.5
I	100.4	102.7	102.2	100.4	102.7	102.3	99.8	102.0	102.1
II	100.7	105.5	104.8	100.8	105.8	105.0	100.4	104.7	104.3
III	100.6	106.2	105.5	100.6	106.4	105.8	101.2	106.5	105.2
IV	100.8	107.4	106.6	100.8	107.8	106.9	101.8	108.1	106.2
1979	99.6	107.8	108.2	99.3	108.0	108.7	101.5	108.2	106.6
I	100.4	108.0	107.6	100.3	108.2	107.9	101.5	108.9	107.3
II	99.8	107.5	107.7	99.4	107.6	108.2	101.5	108.0	106.4
III	99.3	108.0	108.7	98.9	108.0	109.2	101.1	108.0	106.9
IV	99.1	107.9	108.8	98.8	108.0	109.2	102.0	107.9	105.8
1980	98.9	106.2	107.4	98.5	106.3	107.9	101.7	103.6	101.8
I	99.3	107.9	108.7	98.8	107.9	109.3	102.6	107.8	105.1
II	98.2	104.7	106.6	97.6	104.6	107.2	100.5	101.6	101.1
III	98.9	105.3	106.5	98.4	105.3	107.0	100.3	99.9	99.6
IV	99.4	107.0	107.7	99.2	107.3	108.2	103.7	105.0	101.3
1981	100.7	108.9	108.1	99.9	108.6	108.7	104.6	105.9	101.2
I	100.7	109.1	108.3	100.4	109.2	108.8	105.2	106.7	101.4
II	100.7	109.1	108.3	100.1	109.0	108.9	105.1	107.5	102.3
III	101.0	109.6	108.5	100.0	109.1	109.1	105.1	107.4	102.2
IV	100.3	107.8	107.4	99.1	107.1	108.0	103.0	102.0	99.0
1982	101.0	106.4	105.4	99.9	105.8	105.9	103.6	96.5	93.2
I	100.1	106.3	106.2	99.3	106.0	106.7	102.4	98.2	95.9
II	100.4	106.4	106.0	99.5	106.1	106.6	102.6	97.0	94.5
III	101.3	106.7	105.3	100.4	106.3	105.9	104.4	96.6	92.5
IV	102.0	105.9	103.9	100.4	104.9	104.5	104.7	94.2	90.0

Table 4. Output per hour, output, and hours in the total private sector, 1909–82

(Index, 1977=100)

Year	Output per hour of all persons	Output	Hours	Year	Output per hour of all persons	Output	Hours
1909	22.0	13.4	61.0	1945	44.6	34.2	76.7
				1946	43.1	33.3	77.3
				1947	42.9	33.8	78.7
1910	23.2	13.8	59.4	1948	45.3	35.8	79.1
1911	22.1	14.1	63.8	1949	46.2	35.4	76.6
1912	22.7	14.9	65.8				
1913	22.7	15.0	66.2	1950	49.7	38.6	77.7
1914	22.0	14.3	65.1	1951	51.1	40.8	79.9
1915	21.9	14.1	64.4	1952	52.9	42.3	79.9
1916	22.2	15.3	69.0	1953	54.6	44.1	80.8
1917	21.5	15.1	70.4	1954	55.8	43.6	78.2
1918	22.7	15.9	69.9	1955	57.9	47.1	81.3
1919	23.6	16.0	67.7	1956	58.5	48.4	82.7
				1957	60.2	49.1	81.6
1920	22.8	15.7	68.6	1958	62.2	48.6	78.2
1921	23.0	14.2	61.8	1959	64.1	52.0	81.2
1922	25.1	16.7	66.4				
1923	26.3	18.8	71.5	1960	65.1	53.2	81.6
1924	26.8	18.7	69.9	1961	67.4	54.2	80.4
1925	28.1	20.4	72.4	1962	69.9	57.2	81.8
1926	28.9	21.6	74.8	1963	72.4	59.6	82.4
1927	29.0	21.5	74.3	1964	75.4	63.1	83.7
1928	28.8	21.6	75.0	1965	78.0	67.3	86.3
1929	30.3	23.1	76.4	1966	80.4	71.0	88.4
				1967	82.1	72.8	88.7
				1968	84.7	76.4	90.2
1930	28.9	20.6	71.3	1969	85.1	78.8	92.5
1931	28.8	18.9	65.6				
1932	27.3	15.9	58.3	1970	86.0	78.3	91.1
1933	26.8	15.5	57.7	1971	89.0	80.7	90.7
1934	29.6	16.8	56.5	1972	92.0	85.9	93.3
1935	31.0	18.5	59.6	1973	94.3	91.3	96.8
1936	32.9	21.0	63.9	1974	92.7	90.0	97.1
1937	32.9	22.3	67.9	1975	94.8	88.7	93.6
1938	33.7	20.9	62.1	1976	97.7	94.1	96.3
1939	35.1	22.9	65.2	1977	100.0	100.0	100.0
				1978	100.7	105.4	104.7
1940	36.5	24.9	68.2	1979	100.1	108.1	108.0
1941	38.9	28.7	73.8				
1942	39.2	31.2	79.5	1980	99.8	107.2	107.4
1943	40.2	33.1	82.3	1981	101.5	109.8	108.2
1944	42.8	34.8	81.2	1982	101.8	107.7	105.8

Chapter III. Multifactor Productivity in the Private Business Sector

As indicated earlier, the aggregate measure of output per hour of all persons reflects many influences, such as the amount of capital per unit of labor, shifts in resources among industries and sectors, composition of the work force, capacity utilization, and the organization of production. This chapter looks at the influence of one of these— capital per hour of all persons. The BLS index of multifactor productivity, which measures output per unit of combined labor and capital, is, in fact, an index of output per hour of all persons adjusted for the influence of capital per hour. The chapter also reviews trends in output per unit of capital services, which indicate the savings realized over time in the use of physical capital per unit of output. As previously indicated, the analyses in this and the following chapters are based on the *private* business and *private* nonfarm business sectors, which exclude government enterprises.[1]

Trends in multifactor productivity

Tables 8, 9, and 10 and charts 6, 7, and 8 show the annual indexes of multifactor productivity in addition to those for output per hour and output per unit of capital services for private business, private nonfarm business, and manufacturing during the period 1948 to 1981. Several trends are immediately evident from the charts. First, in each of the three sectors, output per hour grew at a faster rate than multifactor productivity. This, as shown later, reflects the growth of capital per unit of labor. Second, multifactor productivity, like output per hour, experienced a marked slowdown in the rate of growth after 1973 in all three sectors. Third, short-term fluctuations in multifactor productivity generally moved in the same direction as those in output per hour; for example, in 1981, both output per hour and multifactor productivity rose in all three sectors but multifactor productivity indexes rose relatively less.

The charts also show that, although output per unit of capital exhibited marked short-term fluctuations between 1948 and 1981, there were no clearly evident trends in this measure during the period as a whole. This means that there were no apparent long-term savings in the amount of capital services required to produce a unit of output. The short-term fluctuations in output per unit of capital are primarily an indication of changes in capacity utilization, the result of cyclical movements in aggregate demand.[2] Capacity utilization is discussed in the next chapter as one of the factors affecting movements in multifactor productivity.

Capital per hour of all persons

The growth in capital intensity—i.e., the amount of capital inputs per person-hour— is one of the major causes of the growth in output per hour during the three decades as a whole. Between 1948 and 1981, output per hour of all persons in the private business sector grew at an average annual rate of 2.4 percent, and this was associated with a 2.6 percent yearly growth rate in capital intensity. The growth rate of capital per hour multiplied by capital's share of total output measures its contribution to the growth in output per hour (table 5). (Table 6 shows the capital and labor shares of total income for 1948-81.) Capital's contribution was 0.9 percent per year, or nearly 40 percent of the growth rate in output per hour between 1948 and 1981. Multifactor productivity, which measures output per combined unit of capital and labor, grew at a yearly rate of 1.5 percent; this is the residual obtained by subtracting the contribution of capital per hour from the growth rate of output per hour.[3]

In the private nonfarm sector, capital per hour of all persons grew at an average annual rate of 2.2 percent from 1948 to 1981, somewhat less than in the business sector because of the large rise in capital-intensive production in farming. The increase in nonfarm capital intensity contributed 0.8 percent per year, or 40 percent, to the 2.0 percent annual rate of growth of output per hour. Multifactor productivity grew at a significantly slower annual rate in private nonfarm business (1.3 percent) than in business; this, too, reflects the technologi-

[1]In 1981, output of government enterprises accounted for 2 percent of total business output.

[2]The index of output per unit of capital input in the manufacturing sector is closely correlated with the Federal Reserve Board index of capacity utilization for total manufacturing. The correlation coefficient between the two series was about 0.9 during the years 1948-81.

[3]See appendix A for a discussion of the multifactor productivity model and the conceptual relationships among the different variables.

Chart 6. Private business sector: Output per hour of all persons, output per unit of capital, and multifactor productivity, 1948-81

(Index, 1498 = 100)

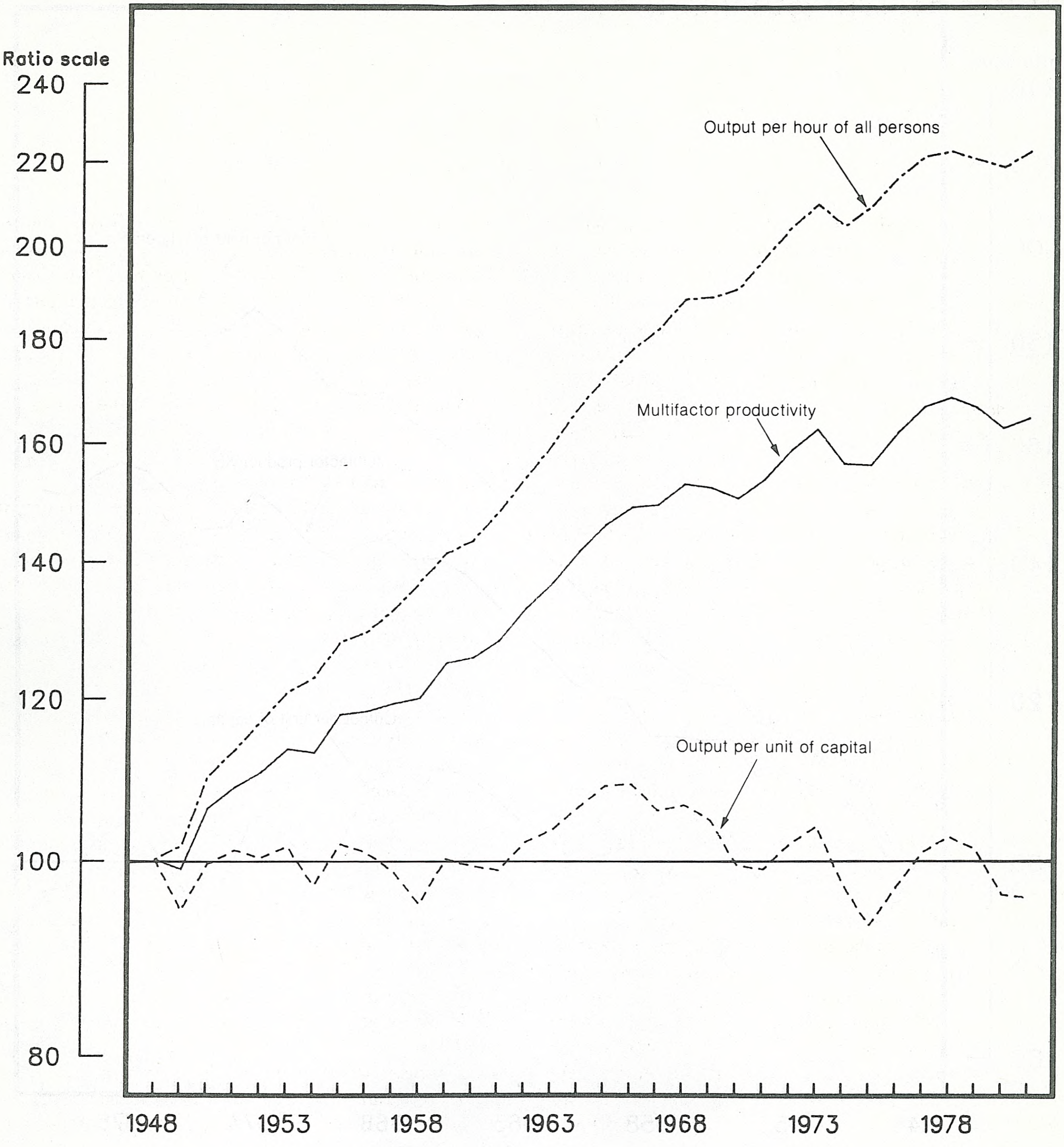


Chart 7. Private nonfarm business sector: Output per hour of all persons, output per unit of capital, and multifactor productivity, 1948-81

(Index, 1948 = 100)

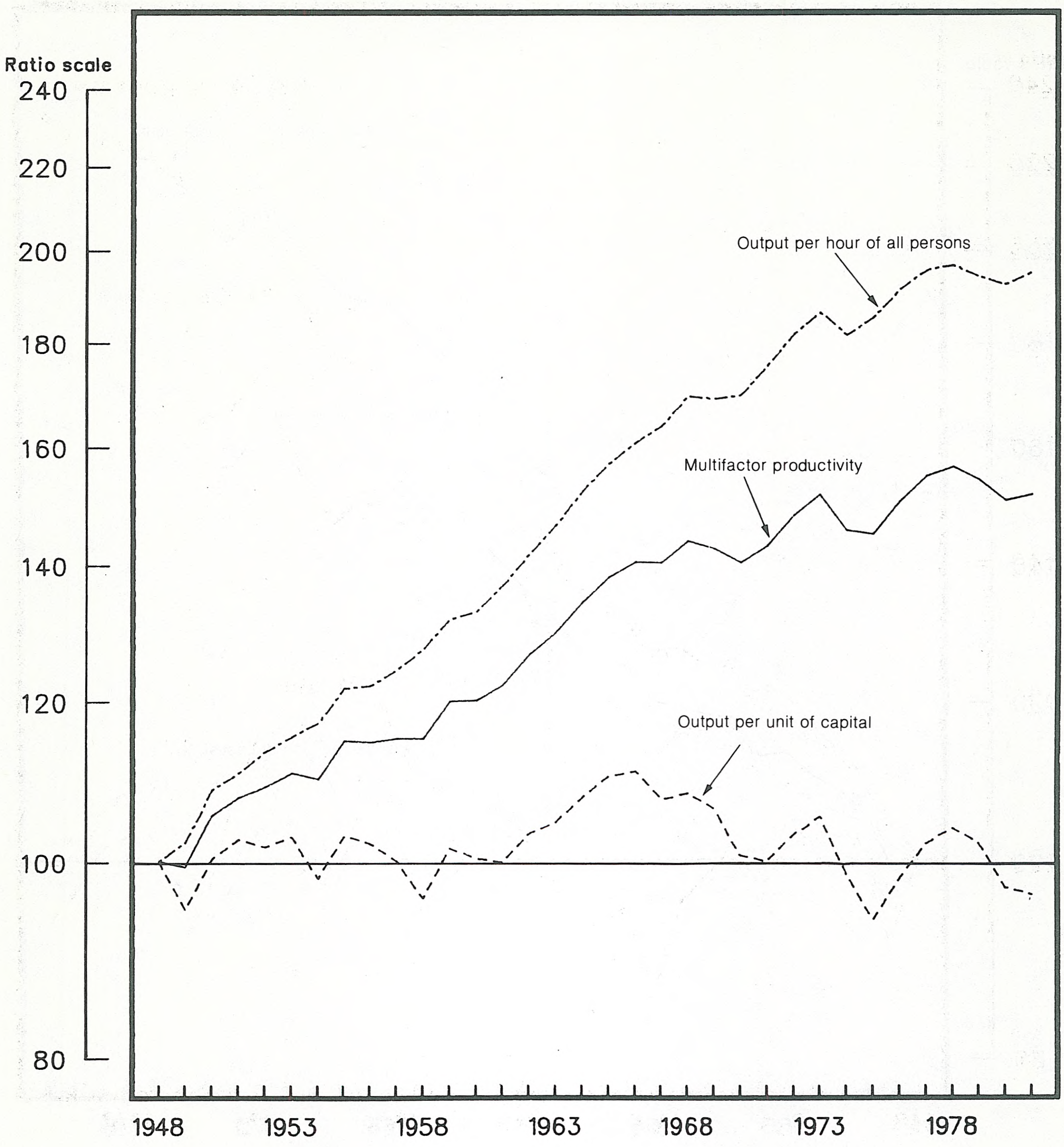


Chart 8. Manufacturing sector: Output per hour of all persons, output per unit of capital, and multifactor productivity, 1948-81

(Index, 1948 = 100)

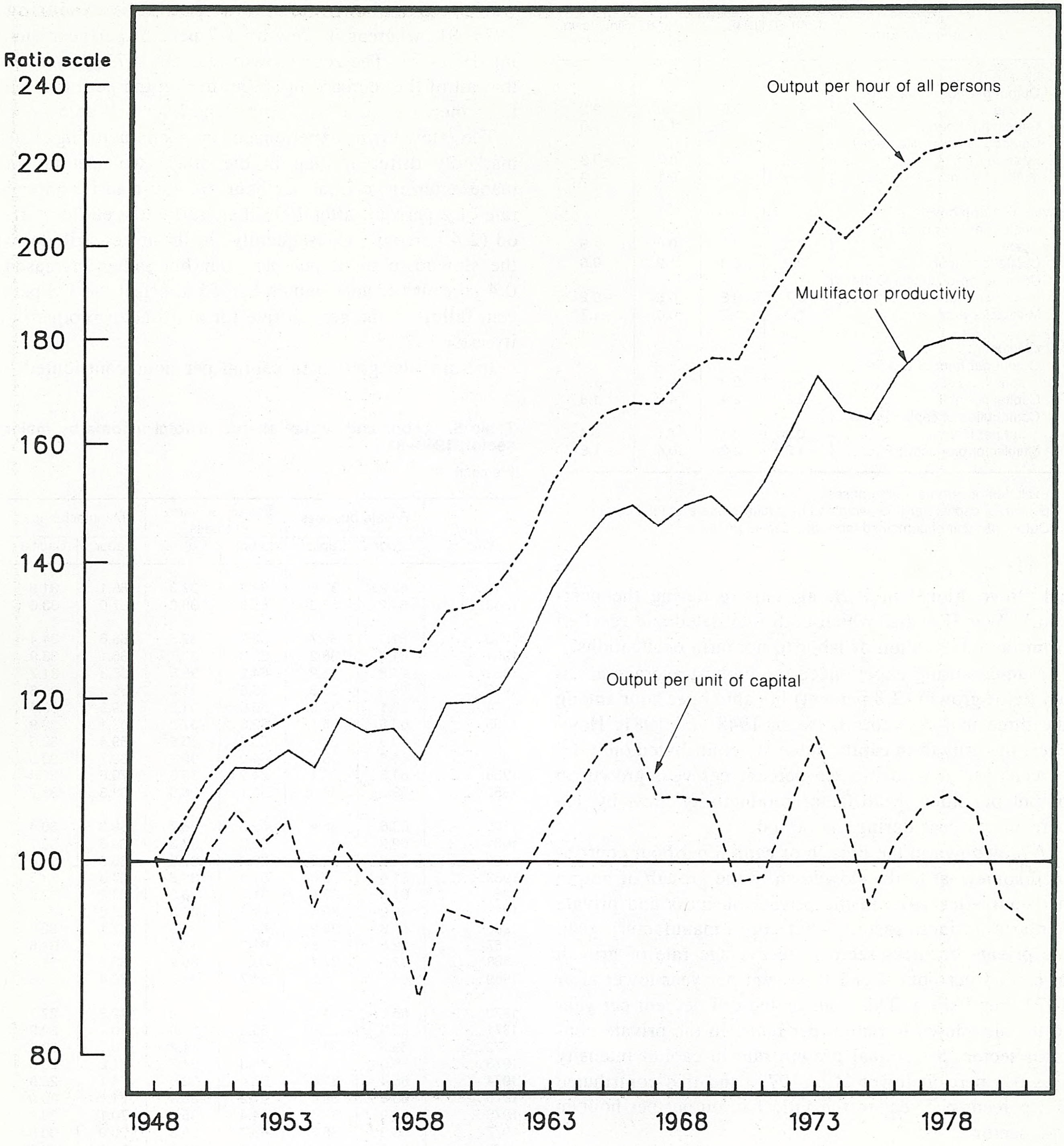


Table 5. Rates of growth in output per hour of all persons, capital per hour, the contribution of capital, and multifactor productivity by major sector, 1948–81

(Percent per year, compounded)

Sector and measure	1948–81 (1)	1948–73 (2)	1973–81 (3)	Slowdown (3)–(2)
Private business:[1]				
Output per hour of all persons	2.4	3.0	0.8	−2.2
Capital per hour	2.6	2.8	1.8	−1.0
Contribution of capital to output per hour[2]	0.9	1.0	0.7	−0.3
Multifactor productivity[3]	1.5	2.0	0.1	−1.9
Private nonfarm business:[1]				
Output per hour of all persons	2.0	2.5	0.6	−1.9
Capital per hour	2.2	2.3	1.2	−0.6
Contribution of capital to output per hour[2]	0.7	0.8	0.6	−0.2
Multifactor productivity[3];	1.3	1.7	0.0	−1.7
Manufacturing:				
Output per hour of all persons	2.6	2.9	1.5	−1.4
Capital per hour	2.8	2.4	4.2	1.8
Contribution of capital to output per hour[2]	0.8	0.7	1.1	0.4
Multifactor productivity[3]	1.8	2.2	0.4	−1.8

[1]Excludes government enterprises.
[2]Growth of capital per hour weighted by capital's share of total output.
[3]Output per unit of combined labor and capital input.

cal "revolution" in U.S. agriculture during the post-World War II years, which both facilitated and resulted from the reallocation of labor to nonfarm occupations.

Manufacturing experienced the highest average annual rate of growth (2.8 percent) in capital per hour among the three major sectors between 1948 and 1981. However, the growth in capital intensity contributed only 0.8 percent per year to the 2.6 percent per year growth in output per hour. Multifactor productivity grew by 1.8 percent per year during the period.

A slowdown in the growth of capital per hour contributed somewhat to the slowdown in the growth of output per hour after 1973 in the private business and private nonfarm business sectors—but not in manufacturing. In the private business sector, the average rate of growth of capital per hour was 1.0 percent per year lower after 1973 than before. This contributed 0.3 percent per year to the slowdown in output per hour. In the private nonfarm sector, the annual growth rate in capital intensity was 0.6 percent lower after 1973, and this contributed 0.2 percent per year to the falloff in output per hour in that sector.

Most of the slowdown in output per hour in the two sectors was associated with decreases in the annual rates of growth of multifactor productivity. In the private business sector, the annual rate of growth in multifactor productivity during 1973-81 was 0.1 percent compared with 2.0 percent during 1948-73, a falloff of 1.9 percent per year. In the private nonfarm business sector, there was no growth in multifactor productivity during 1973–81, whereas it grew by 1.7 percent per year during 1948–73. The zero growth rate for 1973–81 means that all of the increase in output during the period came from increases in capital inputs and hours of labor.

The slowdown experienced in manufacturing was markedly different than in the other two sectors. In manufacturing, capital per hour grew at a faster annual rate (4.2 percent) after 1973 than during the earlier period (2.4 percent). Consequently, it did not contribute to the slowdown in output per hour but rather increased 0.4 percent per year, which helped to offset the 1.8 percent falloff in the growth rate for multifactor productivity after 1973.[4]

In sum, the growth in capital per hour contributed a

Table 6. Labor and capital shares of total income by major sector, 1948–81

(Percent)

Year	Private business		Private nonfarm business		Manufacturing	
	Labor	Capital	Labor	Capital	Labor	Capital
1948	62.2	37.8	62.7	37.3	68.1	31.9
1949	64.2	35.8	65.0	35.0	67.0	33.0
1950	61.3	38.7	62.7	37.3	65.6	34.4
1951	61.8	38.2	62.3	37.7	66.1	33.9
1952	64.8	35.2	64.2	35.8	68.3	31.7
1953	66.4	33.6	65.8	34.2	69.4	30.6
1954	66.1	33.9	65.8	34.2	69.6	30.4
1955	63.3	36.7	62.8	37.2	67.1	32.9
1956	63.9	36.1	63.4	36.6	69.4	30.6
1957	64.6	35.4	64.2	35.8	69.7	30.3
1958	64.6	35.4	64.2	35.8	70.6	29.4
1959	63.5	36.5	63.1	36.9	68.3	31.7
1960	63.6	36.4	63.3	36.7	69.6	30.4
1961	62.9	37.1	62.7	37.3	69.3	30.7
1962	62.2	37.8	62.2	37.8	68.6	31.4
1963	61.4	38.6	61.4	38.6	67.5	32.5
1964	61.6	38.4	61.7	38.3	67.2	32.8
1965	60.9	39.1	61.2	38.8	65.8	34.2
1966	61.8	38.2	62.1	37.9	67.1	32.9
1967	62.5	37.5	62.8	37.2	68.4	31.6
1968	62.9	37.1	63.1	36.9	68.4	31.6
1969	64.5	35.5	64.7	35.3	70.4	29.6
1970	65.8	34.2	65.8	34.2	72.3	27.7
1971	65.0	35.0	65.0	35.0	70.1	29.9
1972	65.6	34.4	65.8	34.2	70.1	29.9
1973	65.0	35.0	65.3	34.7	71.2	28.8
1974	66.4	33.6	66.4	33.6	74.1	25.9
1975	63.8	36.2	64.2	35.8	71.1	28.9
1976	63.9	36.1	64.4	35.6	70.1	29.9
1977	63.3	36.7	63.7	36.3	70.0	30.0
1978	64.3	35.7	64.9	35.1	71.0	29.0
1979	65.4	34.6	66.0	34.0	73.2	26.8
1980	65.5	34.5	66.3	33.7	75.7	24.3
1981	64.6	35.4	65.3	34.7	74.8	25.2

[4]A small percentage of the post-1973 rise in the BLS capital input measures represents spending for pollution abatement which is not reflected in the output measures. Based on estimates made by the Bureau of Economic Analysis, U.S. Department of Commerce, capital inputs for pollution abatement in manufacturing, where the impact was greatest, grew about 0.2 percent per year between 1973

(Continued)

sizable fraction—between 30 and 40 percent—to the longer term growth, from 1948 to 1981, in output per hour of all persons in private business, private nonfarm business, and manufacturing. It also accounted for a small proportion of the post-1973 slowdown in output per hour in private business and private nonfarm business, but not in manufacturing. Thus, most of the long-term growth—as well as the post-1973 slowdown—in output per hour in the three major sectors was associated with movements in multifactor productivity. The next chapter reviews some of the factors that have influenced the movements in multifactor productivity.

Relationship between capital per hour and factor prices

In a competitive economy, changes in the amount of capital per unit of labor reflect, among other things, the behavior of firms trying to minimize their total production costs as relative prices of these factors change. Thus, increases in the price of labor relative to the price of capital services induce firms to shift production techniques from less to more capital-intensive methods. Table 7 shows average annual rates of change of capital per hour (the substitution of capital for labor inputs) and average annual changes in the relative prices of capital and labor for the private business sector. During the period 1948–81 as a whole, the average annual rate of growth of inputs of capital services (3.5 percent) was substantially greater than that for hours of all persons (0.9 percent). This was probably partly in response to the slower rise in the price of capital services (3.4 percent) than in labor services (6.4 percent). That is, the 2.6 percent average annual growth in capital per hour discussed in the previous section may partially reflect a response to a 3.0 percent per year decline in the price of capital services relative to the price of labor inputs (average hourly compensation).[5]

Comparisons of the subperiods before and after 1973 indicate that the slowdown in the rate of growth of capital per unit of labor can largely be explained by the changes in the relative prices of the two factors. As shown in the previous section, the average annual rate of growth of capital per hour of all persons dropped from 2.9 percent in 1948–73 to 1.8 percent in 1973–81. This was the result of a slowdown in the rate of growth of capital inputs coupled with a doubling in the annual rate of increase in hours. The falloff in the growth in capital intensity after 1973 coincided with a slowdown in the rate of decline in the price of capital services relative to hourly compensation. Between 1973 and 1981, the price of capital relative to labor declined 1.7 percent per year, half as fast as the 3.4 percent annual rate of decline during the earlier period, 1948–73.

Table 7. Relationship between changes in rates of growth in capital services per hour and changes in relative factor prices in the private business sector, 1948–81

(Percent per year, compounded)

Measure	1948–81 (1)	1948–73 (2)	1973–81 (3)	Change, 1948–73 to 1973–81 (3)–(2)
Factor inputs:				
Capital services	3.5	3.6	3.2	−0.4
Hours of all persons	0.9	0.7	1.4	0.7
Capital per hour	2.6	2.9	1.8	−1.1
Factor prices:				
Capital services[1]	3.4	2.3	7.2	4.9
Labor[2]	6.4	5.7	8.9	3.2
Relative price[3]	−3.0	−3.4	−1.7	−1.7
Ratio: Capital per hour to relative factor prices	0.9	0.9	1.1	0.2

[1]Implicit price of capital services in the private business sector.
[2]Hourly compensation of all persons in the private business sector.
[3]Numerical (absolute) value of the ratio of the price of capital services relative to hourly compensation of all persons.

The bottom row of table 7 shows the numerical (absolute) value of the ratio of the average annual rate of growth of capital per hour (the capital-labor ratio) to the average annual rate of growth of the price of capital relative to the price of labor.[6] The numerical value of the ratio was 0.9 for the period 1948–81 as a whole; but, more interestingly, it appears to have been fairly stable between the two periods—0.9 during 1948–73 and 1.1 during 1973–81. This suggests that most of the slow-

(Continued)
and 1981, the same rate as between 1960 and 1973. Thus, the capital inputs for pollution abatement appear to have had little effect on the slowdown in productivity; in long-term growth, the overstatement of the contribution of capital inputs to the annual growth rate of "measured" output per hour would be less than 0.1 percentage point. It should also be noted that the equipment can affect productivity in other ways. For example, the pollution abatement investment may embody a less or possibly more efficient technology than the existing one; it may require additional labor inputs, or it may raise worker efficiency if it results in a cleaner and healthier workplace.

[5]The measures of quantity and price of labor services used in this bulletin are based on hours of all persons and average hourly compensation and, therefore, do not take account of changes in the composition of the labor force resulting from the growth in the amount of human capital (e.g., education) per worker. However, this does not affect the broad conclusions in the text because adjusting the series for quality changes would lower the annual rate of growth of capital per unit of labor and the decline in the ratio of the price of capital to the price of labor by the same percentage.

[6]The ratio is a crude estimate of the (negative) value of the elasticity of substitution between capital and labor. The estimate is crude because it ignores technological change, changes in the product mix, and other factors that could affect the capital-labor ratio. It also does not take into account lags between changes in relative factor prices and the capital-labor ratio. For one of many studies on the theory and empirical measurement of the elasticity of substitution, see Murray Brown, *On the Theory and Measurement of Technological Change* (Cambridge, Mass., Cambridge University Press, 1966).

Table 8. Private business sector: Productivity and related measures, 1948–81

Period	Productivity: Output per hour of all persons	Productivity: Output per unit of capital	Productivity: Multifactor productivity[1]	Output[2]	Inputs: Hours of all persons[3]	Inputs: Capital[4]	Inputs: Combined units of labor and capital inputs[5]	Capital per hour of all persons
	Index, 1977=100							
1948	45.3	99.2	60.1	36.8	81.3	37.1	61.3	45.6
1949	46.0	93.6	59.4	36.1	78.6	38.6	60.8	49.1
1950	49.7	98.7	63.6	39.5	79.5	40.0	62.1	50.4
1951	51.2	100.2	65.1	41.8	81.8	41.8	64.3	51.1
1952	52.9	99.4	66.3	43.2	81.8	43.5	65.2	53.2
1953	54.6	100.7	68.0	45.1	82.6	44.9	66.4	54.3
1954	55.6	96.3	67.8	44.4	79.8	46.1	65.5	57.7
1955	57.8	100.9	70.7	47.9	82.9	47.5	67.8	57.3
1956	58.5	100.0	71.0	49.2	84.2	49.2	69.3	58.5
1957	60.0	97.9	71.6	49.7	82.9	50.7	69.4	61.2
1958	61.8	94.3	72.0	48.9	79.0	51.9	67.8	65.6
1959	63.9	99.3	74.9	52.5	82.1	52.9	70.0	64.4
1960	64.8	98.4	75.4	53.3	82.2	54.1	70.7	65.8
1961	67.0	98.0	76.9	54.2	80.9	55.3	70.5	68.4
1962	69.6	101.2	79.7	57.2	82.2	56.6	71.8	68.8
1963	72.3	102.6	82.0	59.7	82.7	58.2	72.9	70.4
1964	75.4	105.2	84.9	63.3	84.0	60.2	74.6	71.6
1965	78.1	107.8	87.6	67.6	86.7	62.8	77.2	72.4
1966	80.4	108.0	89.3	71.3	88.7	66.1	79.9	74.5
1967	82.3	104.9	89.6	72.9	88.6	69.6	81.4	78.5
1968	85.1	105.5	91.7	76.7	90.1	72.7	83.7	80.7
1969	85.3	103.7	91.3	78.9	92.5	76.1	86.5	82.3
1970	86.1	98.6	90.2	78.3	90.9	79.4	86.8	87.4
1971	89.2	98.1	92.2	80.6	90.4	82.2	87.5	91.0
1972	92.4	101.0	95.2	86.0	93.2	85.2	90.4	91.5
1973	94.7	103.0	97.5	91.8	96.9	89.1	94.1	92.0
1974	92.4	96.5	93.8	89.9	97.2	93.1	95.8	95.8
1975	94.5	91.9	93.6	88.0	93.1	95.7	94.0	102.8
1976	97.6	96.1	97.1	93.7	95.9	97.5	96.5	101.6
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	100.6	101.8	101.0	105.5	104.9	103.6	104.4	98.8
1979	99.6	100.3	99.9	107.8	108.3	107.5	108.0	99.3
1980	98.8	95.3	97.6	106.2	107.4	111.3	108.8	103.6
1981	100.6	95.0	98.6	108.8	108.2	114.5	110.3	105.8
	Compound annual percent change							
1948–73	3.0	0.2	2.0	3.7	0.7	3.6	1.7	2.9
1973–81	0.8	−1.0	0.1	2.2	1.4	3.2	2.0	1.8
1948–81	2.4	−0.1	1.5	3.3	0.9	3.5	1.8	2.6

[1]Output per unit of combined labor and capital inputs.

[2]Gross domestic product originating in the sector, in constant dollars.

[3]Paid hours of all employees, plus the hours of proprietors and unpaid family workers engaged in the sector.

[4]A measure of the flow of capital services used in the sector.

[5]Hours of all persons combined with capital input, using labor and capital shares of output as weights.

SOURCE: See appendixes B, C, and D.

Table 9. Private nonfarm business sector: Productivity and related measures, 1948–81

Period	Productivity			Output[2]	Inputs			Capital per hour of all persons
	Output per hour of all persons	Output per unit of capital	Multifactor productivity[1]		Hours of all persons[3]	Capital[4]	Combined units of labor and capital inputs[5]	
	Index, 1977=100							
1948	51.2	98.1	64.6	35.6	69.6	36.3	55.1	52.2
1949	52.3	92.8	64.2	34.9	66.8	37.7	54.4	56.3
1950	55.6	98.4	68.2	38.3	69.0	39.0	56.2	56.5
1951	56.6	100.6	69.5	40.9	72.2	40.6	58.8	56.3
1952	58.0	99.7	70.4	42.2	72.8	42.4	60.0	58.2
1953	59.0	100.9	71.5	44.1	74.7	43.7	61.7	58.5
1954	59.9	96.2	71.0	43.2	72.1	44.9	60.8	62.3
1955	62.3	100.9	74.1	46.8	75.1	46.4	63.2	61.7
1956	62.5	100.1	74.0	48.2	77.0	48.1	65.1	62.5
1957	63.6	98.0	74.3	48.7	76.6	49.7	65.6	64.9
1958	65.1	94.0	74.3	47.8	73.4	50.8	64.3	69.3
1959	67.4	99.5	77.5	51.6	76.6	51.9	66.6	67.7
1960	67.9	98.4	77.6	52.3	77.0	53.2	67.5	69.1
1961	70.0	97.9	78.9	53.3	76.1	54.4	67.5	71.5
1962	72.5	101.3	81.7	56.4	77.8	55.7	69.0	71.6
1963	74.9	102.6	83.8	58.9	78.6	57.4	70.3	73.0
1964	77.8	105.5	86.7	62.7	80.5	59.4	72.3	73.8
1965	80.3	108.1	89.2	67.0	83.5	62.0	75.1	74.2
1966	82.2	108.7	90.7	71.0	86.4	65.3	78.3	75.7
1967	83.8	105.3	90.7	72.5	86.5	68.9	79.9	79.6
1968	86.7	106.0	92.9	76.5	88.2	72.1	82.3	81.7
1969	86.4	104.1	92.1	78.7	91.1	75.6	85.4	83.0
1970	86.8	98.6	90.7	77.9	89.7	78.9	85.9	88.0
1971	89.7	98.0	92.4	80.1	89.3	81.8	86.7	91.5
1972	93.0	101.1	95.7	85.8	92.2	84.8	89.7	92.0
1973	95.3	103.2	97.9	91.7	96.2	88.8	93.6	92.3
1974	92.9	96.5	94.1	89.7	96.6	93.0	95.4	96.3
1975	94.7	91.7	93.6	87.6	92.5	95.6	93.6	103.3
1976	97.8	96.1	97.2	93.6	95.7	97.4	96.3	101.8
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	100.6	101.9	101.1	105.7	105.1	103.7	104.6	98.7
1979	99.3	100.0	99.6	108.0	108.7	107.9	108.4	99.2
1980	98.4	95.1	97.3	106.2	108.0	111.7	109.2	103.4
1981	99.8	94.4	97.9	108.5	108.8	115.0	110.9	105.7
	Compound annual percent change							
1948–73	2.5	0.2	1.7	3.9	1.3	3.6	2.1	2.3
1973–81	0.6	−1.1	0.0	2.1	1.5	3.3	2.1	1.7
1948–81	2.0	−0.1	1.3	3.4	1.4	3.6	2.1	2.2

See footnotes for table 8.

Table 10. Manufacturing sector: Productivity and related measures, 1948–81

Period	Productivity: Output per hour of all persons	Productivity: Output per unit of capital	Productivity: Multifactor productivity[1]	Output[2]	Inputs: Hours of all persons[3]	Inputs: Capital[4]	Inputs: Combined units of labor and capital inputs[5]	Capital per hour of all persons
	Index, 1977=100							
1948	45.1	94.4	56.2	35.8	79.4	37.9	63.7	47.8
1949	46.9	86.0	56.0	33.9	72.4	39.5	60.6	54.5
1950	49.4	94.9	59.9	38.6	78.2	40.7	64.5	52.1
1951	51.1	99.6	62.3	43.0	84.2	43.2	69.1	51.3
1952	52.0	95.7	62.2	44.5	85.4	46.4	71.4	54.4
1953	52.9	98.6	63.5	47.5	89.8	48.2	74.8	53.7
1954	53.7	89.2	62.3	44.1	82.1	49.5	70.8	60.2
1955	56.4	95.8	65.9	48.9	86.6	51.0	74.2	58.8
1956	56.0	92.5	64.8	49.2	87.9	53.2	75.9	60.5
1957	57.1	89.6	65.1	49.5	86.5	55.2	76.0	63.8
1958	56.9	80.5	62.8	45.2	79.4	56.2	71.9	70.7
1959	59.6	89.2	67.0	50.5	84.7	56.6	75.4	66.9
1960	60.0	88.0	67.0	50.7	84.4	57.5	75.6	68.2
1961	61.6	86.9	68.0	50.7	82.3	58.3	74.6	70.9
1962	64.3	92.9	71.5	55.1	85.6	59.2	77.0	69.2
1963	68.9	98.3	76.3	59.6	86.5	60.7	78.2	70.1
1964	72.3	102.4	79.8	63.9	88.4	62.4	80.0	70.6
1965	74.5	107.3	82.8	69.8	93.6	65.1	84.3	69.5
1966	75.3	108.7	83.7	75.1	99.8	69.2	89.8	69.3
1967	75.3	101.1	81.8	75.0	99.6	74.2	91.7	74.5
1968	78.0	101.1	83.7	79.1	101.4	78.2	94.4	77.1
1969	79.3	100.5	84.6	81.7	103.1	81.3	96.6	78.9
1970	79.1	91.8	82.3	77.0	97.3	83.9	93.6	86.2
1971	83.9	92.4	86.0	78.7	93.7	85.2	91.5	90.9
1972	88.2	99.9	91.1	86.2	97.8	86.4	94.7	88.3
1973	93.0	108.2	96.8	95.9	103.2	88.6	99.1	85.9
1974	90.8	99.6	93.0	91.9	101.2	92.2	98.8	91.1
1975	93.4	89.4	92.2	85.4	91.4	95.5	92.6	104.4
1976	97.5	96.1	97.1	93.6	95.9	97.4	96.4	101.5
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	100.9	101.5	101.0	105.3	104.4	103.8	104.2	99.4
1979	101.6	99.5	101.0	108.2	106.5	108.8	107.2	102.1
1980	101.7	90.0	98.6	103.6	101.8	115.1	105.1	113.1
1981	104.5	87.5	99.9	105.9	101.3	121.1	106.0	119.5
	Compound annual percent change							
1948–73	2.9	0.6	2.2	4.0	1.1	3.5	1.8	2.4
1973–81	1.5	−2.6	0.4	1.2	−0.2	4.0	0.9	4.2
1948–81	2.6	−0.2	1.8	3.3	0.7	3.6	1.6	2.8

See footnotes for table 8.

down in the growth of capital per hour after 1973 was the result of the change in relative factor prices—the markedly slower rate of decline in the ratio of the price of capital to the price of labor. If the ratio (0.9) for the 1948–81 period as a whole was, in fact, the same in both subperiods, the smaller rate of decline in the price of capital relative to that of labor (1.7 percent per year) would alone have accounted for about 80 percent of the slowdown in the growth of the capital-labor ratio after 1973.[7]

[7]Econometric estimates based on a model derived from the constant-elasticity-of-substitution production function relating the capital-labor ratio to relative factor prices and including dummy variables indicates an elasticity of substitution of 0.9 for the period 1948-81 as a whole. There was no statistically significant difference in the elasticity between 1948-73 and 1973-81. The qualifications discussed in the previous footnote also apply here. Part of the slowdown in the rate of substitution of capital for labor after 1973 may also reflect the sharp increases in energy prices that began in that year. Dale Jorgenson and others have estimated that energy and physical capital are complementary, whereas energy and labor are substitutes in production. This implies that the sharp rise in energy prices in 1973 (and 1979) would have induced firms to decrease their investment and to increase their employment more than they otherwise would have done. Such an energy-induced substitution of capital for labor would be reflected in the figures in table 7 and, to that extent, the effect of change in relative factor prices on the slowdown in capital intensity would be overstated. See Dale W. Jorgenson, "Energy and the Future of the U.S. Economy," *Wharton Magazine*, Vol. 3 (Summer 1979), pp. 15-21.

Chapter IV. Sources of Change in Multifactor Productivity

This chapter reviews several of the statistically observable sources of change in multifactor productivity to see how they have influenced long-run growth in productivity and the slowdown after 1973. These sources include (1) intersectoral shifts in resources, (2) selected changes in labor force composition, (3) changes in capacity utilization, (4) research and development (R&D), and (5) changes in hours at work relative to hours paid.

Intersectoral shifts

Multifactor productivity is increased when labor and capital shift to sectors where they are more productively employed. The most dramatic shift of resources during the period 1948–81 was from the farm to the nonfarm sector. In 1948, persons engaged in farming accounted for about 16 percent of the total engaged in the private business sector; by 1973, the proportion had dropped to 5 percent; and by 1981, to about 4 percent.[1] Capital also moved from the farm to the nonfarm sector during the post-World War II period. As in the case of labor, the shift was virtually completed by the mid-1960's.

Table 11 shows the contribution of intersectoral shifts in labor to the growth rates of multifactor productivity in the private business sector.[2] Because of data limitations, resource reallocation effects reflect only shifts among the three major sectors—farm, manufacturing, and nonfarm-nonmanufacturing. Over the total period, 1948–81, the reallocation of labor, mainly from the farm to the nonfarm sector, contributed 0.1 percent per year to the average annual growth rate of multifactor productivity. Intersectoral shifts in labor contributed 0.2 percentage point to the growth rate of multifactor productivity betwen 1948 and 1973; but it was not a contributing factor after 1973. Thus, 0.2 percentage point of the 1.9 percent slowdown in multifactor productivity growth after 1973 in the private business sector resulted from the fact that there were no longer large numbers of workers moving from farm to nonfarm activities.

Table 11. Contribution of intersectoral shifts in labor to rates of growth in multifactor productivity in the private business sector, 1948–81

(Percent per year, compounded)

Item	1948–81 (1)	1948–73 (2)	1973–81 (3)	Slowdown (3) − (2)
Multifactor productivity	1.5	2.0	0.1	−1.9
Contribution of intersectoral shifts of labor	0.1	0.2	0.0	−0.2
Multifactor productivity adjusted for intersectoral shifts of labor	1.4	1.8	0.1	−1.7

Changes in labor force composition

The BLS measures of multifactor productivity are based on hours of all persons engaged in the private business sector, which assumes that workers are homogeneous with respect to skills. As a result, the shifts from less to more skilled labor because of increased education or on-the-job training are not reflected in the BLS measure of labor input but instead contribute to growth in multifactor productivity.[3]

Historically, the change in the composition of the labor force has been one of the most important sources of growth in multifactor productivity. This includes, among other things, changes in the amount of formal education and on-the-job training per worker, in the age-sex distribution of the labor force, and in the occupational and industry mix of employment. Three of these compositional changes are discussed in this section: The amount of education per worker, which is by far the most important; the age-sex composition of the work force; and increases in the efficiency of an hour's work resulting from the secular decline in average weekly hours.

Education is generally viewed as one of the major factors affecting the productivity of labor. Over the last three decades, the amount of schooling of U.S. workers

[1] The shift was largely completed by 1965; in that year, the number engaged in farming accounted for only 7 percent of all persons engaged in private business. The importance of farm output also declined—from about 6 percent of business output in 1948 to 3 percent in 1973.

[2] The contributions from intersectoral shifts in capital are not included in table 11 because they are already reflected in the BLS measure of capital per hour and, hence, accounted for in the BLS measure of multifactor productivity shown in the table.

[3] For a detailed review of the issues in measuring the effects of changes in the composition of labor inputs on productivity, see Kent Kunze, "Evaluation of Work-Force Composition Adjustment," in National Academy of Sciences, *Measurement and Interpretation of Productivity* (Washington, NAS, 1979).

has increased dramatically.[4] The proportion of the labor force with at least 1 year of college rose from 12 percent in 1948 to 36 percent in 1981; the proportion with 1 to 4 years of high school rose from 47 percent to 55 percent; and the fraction in the lowest education group, those with only 8 or fewer years of schooling, dropped from 41 percent to 8 percent (table 12). There was also a marked rise between 1948 and 1981 in the percentage of students who completed 4 years of high school. The picture was generally the same for men and women.

Table 13 shows Denison's estimates of average annual growth rates in the amount of education per worker during the periods discussed in this bulletin; it also includes his estimates of the growth in efficiency of an hour's work resulting from the decline in the average workweek, and an index of average annual change in the age-sex composition of total hours.[5] The numbers in the last three columns of the table show the contribution of each of these factors to the growth in the BLS measure of multifactor productivity based on the BLS weight for labor's share (65 percent).[6]

Table 12. Percent distribution of the labor force by years of school completed, by sex, 1948, 1973, and 1981

Labor force group and years	Total	Elementary		High school		College	
		Less than 5 years	5–8 years	1–3 years	4 years	1–3 years	4 years or more
Total:							
1948	100.0	7.5	33.5	19.8	27.2	6.9	5.2
1973	100.0	2.0	11.6	18.6	39.4	14.2	14.1
1981	100.0	1.2	6.7	14.9	40.9	17.9	18.3
Men:							
1948	100.0	8.8	35.7	20.2	23.1	6.6	5.7
1973	100.0	2.4	13.1	18.6	35.8	14.5	15.6
1981	100.0	1.5	7.9	15.4	37.5	17.4	20.3
Women:							
1948	100.0	4.4	28.0	18.8	37.3	7.5	4.0
1973	100.0	1.4	9.2	18.6	45.2	13.8	12.0
1981	100.0	.8	5.1	14.2	45.5	18.6	15.7

SOURCES: Data for 1948 from Edward F. Denison, *Accounting for United States Economic Growth, 1929–69* (Washington, The Brookings Institution, 1974). Data for 1973 and 1981 from *Labor Force Statistics Derived from the Current Population Survey: A Databook*, Vol. 1, Bulletin 2096 (Bureau of Labor Statistics, September 1982).

Table 13. Adjustments to hours measures for changes in composition of labor input[1]

Item	Annual growth rate			Contribution to multifactor productivity[2]		
	1948–81	1948–73	1973–81	1948–81	1948–73	1973–81
Total	—	—	—	0.4	0.4	0.4
Amount of education	0.7	0.6	0.7	0.4	0.4	0.5
Efficiency of an hour's work[3] ..	0.2	0.2	0.1	0.1	0.1	0.1
Age-sex composition	−0.2	−0.2	−0.3	−0.1	−0.1	−0.2

[1]Based on Edward Denison's estimates rounded to a tenth of a percentage point. See Denison, *Accounting for United States Economic Growth, 1929–69*, and his *Accounting for Slower Economic Growth: The United States in the 1970's* (Washington, The Brookings Institution, 1979).

[2]Contribution to multifactor productivity is equal to the annual growth rate multipled by the BLS estimate of labor's share (0.65).

[3]Efficiency of an hour's work as affected by changes in hours due to *intragroup changes and specified intergroup shifts.*

The amount of education per worker is, by far, the most important single source of the measured changes in the composition of labor input. Denison's estimates indicate that the amount of education per person in the labor force grew at an average annual rate of 0.7 percent between 1948 and 1981. This was only 0.2 percentage point lower than the annual growth rate of hours of all persons; it means that quality enhancement in the work force from increased education grew nearly as much as the quantity of ''raw'' labor inputs measured by total hours of all persons. When weighted by the BLS estimate of labor's share of total output, Denison's estimate shows that the growth in education per worker contributed about 0.4 percent per year to the annual rate of growth of the BLS measure of multifactor productivity between 1948 and 1981. Changes in the amount of education per worker did not contribute to the falloff in the growth rate of multifactor productivity after 1973 and, judging from Denison's estimates, may even have added nearly 0.1 percentage point to growth.

Average weekly hours in the private business sector declined from 42.5 in 1948 to 38.4 in 1973 and to 36.7

[4]The literature on human capital (including education) and its implications for productivity is too extensive to cite here. For a recent attempt to measure the stock of human capital, see John W. Kendrick, *The Formation and Stocks of Total Capital*, National Bureau of Economic Research (New York, Columbia University Press, 1976) and the literature cited there; for an earlier review of the relationship, see Zvi Griliches, ''Notes on the Role of Education in Production Functions and Growth Accounting,'' in W. Lee Hansen, ed., *Education, Income, and Human Capital*, Studies in Income and Wealth No. 35, National Bureau of Economic Research (New York, Columbia University Press, 1970).

[5]Edward F. Denison kindly made these estimates available to us. Denison's index of the amount of education is based on a weighted distribution of full-time-equivalent business employment by years of schooling and sex. The weights are relative earnings for 1959 standardized for age, race, region, and farm-nonfarm employment. He also makes some adjustment for differences in ability and socioeconomic status.

Similarly, Denison's annual index showing changes in the age-sex composition of the work force is based on a weighted distribution of total hours worked in the business sector by age and sex. The weights are relative hourly earnings of the different demographic groups. For a discussion of the methodology used in arriving at these estimates, see Denison, *Accounting for United States Economic Growth, 1929–69*.

[6]The BLS measures of multifactor productivity employ a Tornquist index number formula which involves changing weights; however, labor's share for the private business sector was fairly stable between 1948 and 1981—about 65 percent of total output—so that the use of a fixed weight does not significantly affect the results.

in 1981. These declines reflect both decreases in average hours worked within sectors and the shift of labor from the farm to the nonfarm sector, where average weekly hours tend to be shorter. Denison has also estimated changes in the efficiency of an hour's work resulting from those intrasectoral changes in average weekly hours and intersectoral shifts in labor. According to his measure, the efficiency of an hour's work due to the combination of these two sources rose about 0.2 percent per year between 1948 and 1981. Multiplying this by the BLS estimate of labor's share indicates that the contribution of the shorter workweek added 0.1 percent per year to the growth of multifactor productivity during the period. The contribution was apparently the same before and after 1973, so that changes in efficiency from the shorter workweek were not a factor in the productivity slowdown.

Work experience, like schooling, is a major component of the composition of the labor force that influences multifactor productivity. Unfortunately, data are not available for directly measuring changes in the average work experience of the total work force, so researchers have had to develop a measure from available data that is closely associated with the desired one. The measure generally used is an index showing changes in the age-sex composition of the labor force.[7] For example, teenagers entering the labor force for the first time probably have little or no work experience and, consequently, an increase in their relative importance tends to reduce the average amount of experience per worker. The measure is stratified by sex because, in general, women tend to have less work experience than men of the same age, either because they enter the labor force later after raising children or because they temporarily leave the labor force to raise children.

Between 1948 and 1981, the proportion of the civilian labor force between 16 and 24 years of age increased from 19.5 percent to about 23 percent; over the same time period, the proportion of women in the civilian labor force rose from about 29 percent to 43 percent. Both of these shifts tended to have a dampening effect on the average number of years of work experience of the labor force during the period.

Denison, like others, has tried to estimate the changes in the average amount of experience of labor inputs by using an index showing changes in the age-sex composition of the labor force. This index declined about 0.2 percent per year between 1948 and 1981, which implies that changes in the age-sex composition of the labor force reduced the annual rate of growth of the BLS measure of multifactor productivity by 0.1 percentage point during the period. The rate of decline in the age-sex composition index appeared to be slightly higher after than before 1973 and thus may have contributed slightly (less than 0.1 percent per year) to the productivity slowdown. That is, it offset the equally slight positive effect from the increased amount of education per worker.

In sum, based on Denison's estimated growth rates and BLS weights, the total combined changes in the composition of labor inputs accounted for about 0.4 percentage point of the 1.5 percent annual growth rate in multifactor productivity between 1948 and 1981.[8] The compositional changes in the work force, considered as a whole, had virtually no effect on the productivity slowdown after 1973.

Capacity utilization

Short-term fluctuations in aggregate demand result in cyclical changes in the utilization of capital and labor, and these too are reflected in the BLS measures of multifactor productivity. This is evident from looking at the cyclical fluctuations in multifactor productivity between 1948 and 1981 (charts 6, 7, 8), and it is perhaps most clearly seen in the 1973–75 recession. Multifactor productivity in each of the three sectors declined from a peak in 1973, bottomed out in 1975, and recovered in 1976. These changes paralleled those in output per unit of capital, which also reflects utilization of the capital stock.

To some extent, the labor inputs are adjusted to current production needs by firms hiring and laying off workers and by changing the number of weekly hours worked. However, to the extent that labor is a quasi-fixed factor and there is labor hoarding, firms tend to underutilize (overutilize) the work force during periods of recession (expansion), and this is reflected in the BLS measures of multifactor productivity.

In the case of capital, firms mainly adjust their inputs to meet changes in their short-run production needs by changing the utilization of existing stocks.[9] The magni-

[7]That is, the index showing changes in the age-sex composition of the labor force is used as a proxy for changes in the average amount of work experience per person.

[8]In the formulation of "growth accounting," the growth of output is related to the growth of inputs of labor, capital services, and other factors. Labor inputs are generally measured by combining hours of all persons and the compositional changes in the labor force, and the growth rate of this aggregate is then weighted by labor's share of the total output in order to determine its contribution to the growth of output. The figures in the text suggest that these combined labor inputs contributed 1.0 percent per year to the rate of growth of output in the private business sector between 1948 and 1981; of this, 0.6 percentage point came from hours of all persons and 0.4—or 40 percent—from the effects of changes in the composition of the work force.

[9]The Tornquist index number formula used to construct the BLS measure of capital stock implicitly adjusts, to some degree, for changes in the utilization of capital. For a theoretical discussion of this implicit ex post adjustment, see Charles R. Hulten, "Productivity Change, Capacity Utilization, and the Sources of Efficiency Growth," BLS Working Paper 137 (Bureau of Labor Statistics, June 1983).

tude of the adjustments for the utilization of capital inputs is therefore likely to be larger than that for labor.

Unfortunately, there is at present no generally accepted way to adjust the labor and capital input series in the private business or nonfarm business sectors for changes in capacity utilization resulting from fluctuations in aggregate demand. The approach used in this bulletin has been to calculate growth rates between cyclical peaks as designated by the National Bureau of Economic Research (see chapter II), but it is not clear that the rates of utilization of the capital stock were the same at each peak; it is equally problematical for labor utilization.[10]

The Federal Reserve Board (FRB) indexes of capacity utilization for total manufacturing can be used to *suggest* the effects of changes in resource utilization on the BLS measures of multifactor productivity in the manufacturing sector.[11] It is important to stress that the adjustments are only suggestive because different published measures of capacity utilization yield somewhat different results and, to some unknown extent, the BLS multifactor productivity measure implicitly incorporates adjustments for changes in resource utilization.[12]

Table 14 compares the growth rates for the BLS multifactor productivity measure for total manufacturing unadjusted and adjusted for capacity utilization based on the FRB index. This was done by adjusting the BLS annual measures of capital inputs in manufacturing by the FRB annual indexes of capacity utilization in that sector.

Table 14. Rates of growth in multifactor productivity in manufacturing, unadjusted and adjusted for utilization of physical capital, 1948–81

(Percent per year, compounded)

Item	1948–81 (1)	1948–73 (2)	1973–81 (3)	Slowdown (3) − (2)
Multifactor productivity[1]	1.8	2.2	0.4	−1.8
Contribution of utilization[2] ...	0.0	0.1	−0.3	−0.4
Adjusted multifactor productivity[3]	1.8	2.1	0.7	−1.4

[1]From table 3.

[2]Average annual rates of growth of capacity utilization weighted by capital's share of total output.

[3]Multifactor productivity minus the contribution of utilization of physical capital.

According to the FRB index, the rate of capacity utilization in manufacturing in 1948 was only slightly higher than in 1981 and, as a consequence, the average annual rate of change was virtually zero. For 1948–81 as a whole, the average annual rate of growth in the adjusted multifactor productivity measure is the same as the unadjusted one.

The results, however, do suggest that some of the productivity slowdown after 1973 may be explained by changes in capacity utilization. The FRB index shows that the rate of capacity utilization rose from 82.5 percent in 1948 to 87.6 percent in 1973 and then fell to 78.5 percent in 1981. The figures based on the adjusted capital inputs indicate that the increase in capacity utilization before 1973 added 0.1 percent per year to the annual growth rate in the BLS (unadjusted) measure of multifactor productivity during 1948–73, and that the decrease in capacity utilization after 1973 reduced it by 0.3 percent per year during 1973–81. Thus, multifactor productivity adjusted for changes in capacity utilization grew at an average annual rate of 0.7 percent in 1973–81 compared with 2.1 percent in 1948–73. This slowdown of 1.4 percent per year in the adjusted measure is 0.4 percentage point lower than the 1.8 percent per year falloff registered by the BLS (unadjusted) series.

In sum, these tentative calculations suggest that changes in capacity utilization may have accounted for a significant fraction of the post-1973 falloff in manufacturing productivity, but that a large fraction probably still remains unexplained. The parallel cyclical movements of multifactor productivity in the three major sectors (charts 6, 7, and 8) also suggest that these general conclusions for manufacturing might be true for the private business and private nonfarm business sectors as well.

Finally, it is interesting to note the virtually parallel fluctuations in the FRB index of capacity utilization for total manufacturing and the BLS measure of output per unit of capital input in the sector (chart 9). During the period 1948–81 as a whole, the association between the two indexes was close; about 80 percent of the total variation in output per unit of capital input could be ''explained'' by variations in capacity utilization.[13]

[10]Arthur Okun and Robert Solow made relative utilization of labor and capital functions of the unemployment rate and used the same measure to adjust both inputs simultaneously. Denison painstakingly measures the ''effects'' of varying intensity of demand on output per unit of input as a function of the ratio of nonlabor earnings to national income of corporations and he, too, applies the same measure of utilization rates to labor and capital. See A.M. Okun, ''Potential GNP: Its Measurement and Significance,'' *Proceedings of the Business and Economics Statistics Section of the American Statistical Association*, 1962, pp. 98–104; R.M. Solow, ''Technical Change and the Aggregate Production Function,'' *Review of Economics and Statistics,* (August 1957), pp. 312–20; and Denison, *Accounting for United States Economic Growth*.

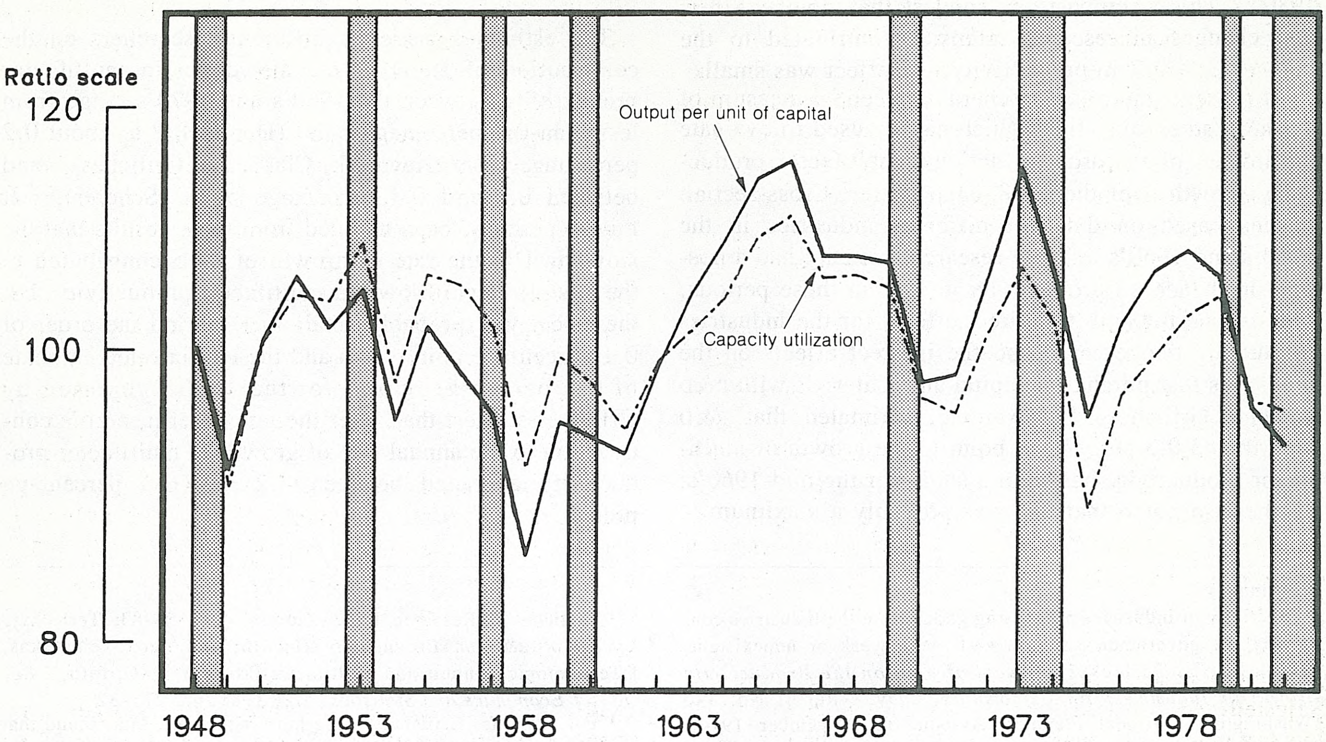
[11]The main reason for using the Federal Reserve Board indexes rather than other measures of capacity utilization is their availability for the total period, 1948–81.

[12]For a review of the issues, see Frank de Leeuw, Lawrence R. Forrest, Jr., Richard D. Raddock, and Zoltan E. Kenessey, *Measures of Capacity Utilization: Problems and Tasks* (Washington, Board of Governors of the Federal Reserve System, July 1979).

[13]The two measures are not wholly independent because the FRB measure of capacity utilization is at least partially based on measures of output and capital stock, albeit not the BLS series. Also, the BLS measures of output per unit of capital input for both the private business and private nonfarm business sectors exhibit equally high correlations with the FRB index of capacity utilization in manufacturing. On the face of it, this would indicate that the large fluctuations in the BLS series of output per unit of capital largely reflect changes in capacity utilization and hence fluctuations in aggregate demand.

Chart 9. Output per unit of capital and rate of capacity utilization in manufacturing, 1948–81

(Index, 1948 = 100)



NOTE: Shaded areas indicate recessions.

Research and development

Additions to the stock of knowledge that yield technological improvements in production are generally viewed as one of the major sources of growth in multifactor productivity. Research and development (R&D) expenditures that contribute to this new knowledge have consequently been a major area of research for explaining the growth in productivity. In addition, the slowdown in the rate of growth of R&D during the 1970's focused attention on its possible role in the productivity slowdown.

Unfortunately, the relationship between R&D expenditures and multifactor productivity is one of the most difficult and, perhaps, more intractable areas of productivity research. The analysis used to relate R&D to multifactor productivity treats R&D expenditures measured in constant prices as gross investment in the capital stock of technical knowledge, and this raises a number of very difficult conceptual and empirical problems.[14] It is, therefore, not surprising that present knowledge about the contribution of R&D to the long-term growth of multifactor productivity and its falloff in the 1970's is limited.

Total R&D expenditures as a percentage of GNP, a measure of "research intensity," declined from 2.7 percent in 1961 to 2.3 percent in 1973; there was virtually no change in the rates between 1973 and 1980. The total figures include R&D expenditures by the U.S. Government for defense, the atomic energy program, and space exploration, and there has been some question about the degree to which these government R&D outlays affect *measured* productivity in the private business sector of the economy.[15] Private R&D expenditures (which ex-

[14]Some of the more obvious problems are: (1) determining the relevant R&D expenditures that affect multifactor productivity; (2) R&D expenditures measure the cost of inputs, not the value of the output of knowledge; (3) there is no appropriate deflator for R&D presently available and researchers have generally used the GNP deflator; (4) the difficulty of measuring the length and structure of the lag between R&D outlays and their impact on multifactor productivity; (5) the meaning and measurement of depreciation and obsolescence of the R&D capital stock; (6) determining the spillover effects (externalities) of R&D among industries using the products of the industry undertaking the R&D as well as between defense and space exploration projects and the private business sector; and (7) the usual quality problems in the price series used to deflate the value of the products embodying the improved technology. For a review of these and other conceptual and empirical issues in relating R&D expenditures to multifactor productivity, see Z. Griliches, "Issues in Assessing the Contribution of Research and Development to Economic Growth," *Bell Journal of Economics*. Spring 1979, pp. 92–116.

[15]Nestor Terleckyj found no correlation between government-contract R&D (other than for agriculture) and the productivity of the industries conducting it. He also found that the indirect effects on

(Continued)

clude outlays by the three government agencies) as a percentage of GNP actually rose from 1.2 percent in 1961 to 1.4 percent in 1973 and to 1.6 percent in 1980.[16] These comparisons suggest that, to the extent that changes in research intensity contributed to the post-1973 falloff in productivity, the effect was small.

At present, there is no generally accepted measure of the R&D stock over time which can be used to evaluate the impact of research on national multifactor productivity growth over the 1948–81 period.[17] Cross-section studies based on data for different industries in the 1950's and 1960's indicate research intensity had a positive influence on productivity growth in these periods. This is true for both the direct effects for the industries conducting the research and the indirect effects on the industries that purchased capital and materials with R&D content. Griliches, for example, estimated that R&D contributed 0.3 percentage point to the growth of multifactor productivity based on a study for the mid-1960's; but he also noted that this was probably a maximum.[18] The findings based on cross-section analyses for the 1970's are mixed; they depend upon the particular sample used and the level of aggregation of the data.[19]

The estimates made by different researchers on the contribution of R&D to the slowdown in multifactor productivity between the 1960's and 1970's range from less than 0.1 percentage point (Denison)[20] to about 0.2 percentage point (Kendrick, Clark, and Griliches)[21] and between 0.2 and 0.4 percentage point (Scherer).[22] It might, perhaps, be concluded from these results that the slowdown in the rate of growth of R&D contributed to the post-1973 slowdown in multifactor productivity, but the effect was probably small, perhaps on the order of 0.1 percentage point. This and the earlier cited estimate of 0.3 percentage point for the 1960's reported by Griliches suggest that, over the longer term, R&D's contribution to the annual rate of growth of multifactor productivity averaged between 0.2 and 0.3 percentage point.

(Continued)
productivity of industries purchasing goods from the industries conducting the government-contract R&D were weak or nonexistent. See Nestor E. Terleckyj, *Effects of* R&D *on the Productivity Growth of Industries: An Exploratory Study*,'' Report No. 140 (Washington, National Planning Association, December 1974). Griliches omits R&D expenditures by the Defense Department, the Atomic Energy Commission, and the National Aeronautics and Space Administration, in order to arrive at an estimate of ''expenditures with probable effects on measured private productivity.'' Government R&D outlays by these three agencies accounted for half of the total R&D expenditures in 1970. See Zvi Griliches, ''Research Expenditures and Growth Accounting,'' in B.R. Williams, ed., *Science and Technology in Economic Growth* (London, 1973) table 3.1, p. 75.

[16]Civilian R&D expenditures accounted for about 70 percent of total R&D outlays in 1980 compared with 62 percent in 1973 and 44 percent in 1961. However, even this series is not appropriate for determining the relationship of R&D to multifactor productivity because it includes research outlays by government, universities, colleges, other nonprofit institutions, and even consumer product research by profitmaking firms, that do not affect the amount of inputs required to produce a unit of output included in the BLS measures. See Griliches, ''Research Expenditures,'' pp. 74–77, and Denison, *Accounting for Slower Economic Growth: The United States in the 1970's* (Washington, The Brookings Institution, 1979), p. 124.

[17]John Kendrick has developed a time series for the stock of R&D capital beginning in 1929. Based on this, he estimated that between 1948 and 1978, the growth of R&D capital contributed about 0.8 percentage point per year to the growth of multifactor productivity (i.e., his total factor productivity). This is about 3 times as large as estimates made by Griliches and others based on cross-section analysis. Kendrick obtains this result because his measure of the stock of R&D capital includes total R&D, both government and privately financed, and, as pointed out in the text and footnote 15, most government-financed R&D has little or no effect, directly or indirectly, on measured multifactor productivity. See John W. Kendrick, ''Why Productivity Growth Rates Change and Differ,'' in Herbert Giersch, ed., *Towards an Explanation of Economic Growth*, Symposium 1980 (Tubingen, J.C.B. Mohr (Paul Sieback), 1981), and Edwin Mansfield's *Comment*.

[18]Griliches, ''Research Expenditures,'' pp. 59–83; Terleckyj, *Effects of* R&D *on Productivity Growth*; and Leo Sveikauskas, ''Technological Inputs and Multifactor Productivity Growth,'' *Review of Economics and Statistics*, May 1981, pp. 275–82.

[19]For example, Griliches, using more aggregate data, found that the growth in productivity was much less sensitive to R&D intensity in manufacturing in the 1970's than in the 1960's and that the 1970's estimate was not significantly different from zero. Taken at face value, this would imply that developments in R&D were a major cause of the slowdown in productivity during the 1970's. However, in his later studies with associates using more disaggregated data, he found that R&D continued to have a positive effect on multifactor productivity in manufacturing during the 1970's. See Zvi Griliches, ''R&D and the Productivity Slowdown,'' *American Economic Review*, May 1980, pp. 343–48; Kim B. Clark and Zvi Griliches, ''Productivity Growth and R&D at the Business Level: Results from the PIMS Data Base,'' Working Paper No. 916 (Cambridge, Mass., National Bureau of Economic Research, June 1982); and Zvi Griliches and F. Lichtenberg, ''R&D Productivity Growth at the Industry Level: Is There Still a Relationship?'' Working Paper No. 850 (Cambridge, Mass., National Bureau of Economic Research, February 1982). Clark and Griliches point out that the PIMS data base is not a representative sample of firms in any given sector; but, interestingly, their estimate of the direct rate of return for the firms in the PIMS data base (18–20 percent) is about the same as the one estimated by Griliches and cited earlier. Clark and Griliches conclude that about 10 percent of the decline in multifactor productivity for the firms in the PIMS data base can be attributed to a reduction in their R&D-to-sales ratio.

[20]Edward F. Denison, ''Accounting for Slower Economic Growth: An Update,'' paper prepared for the Conference on International Comparisons of Productivity and Causes of the Slowdown held by the American Enterprise Institute, Washington, Sept. 30, 1982, p. 25.

[21]John W. Kendrick, ''Survey of the Factors Contributing to the Decline in U.S. Productivity Growth,'' in *The Decline in Productivity Growth*, Conference Series No. 22 (Boston, Federal Reserve Bank of Boston, June 1980); and Clark and Griliches, ''Productivity Growth and R&D at the Business Level.''

[22]F.M. Scherer, ''R&D and Declining Productivity Growth,''
(Continued)

Hours at work versus hours paid

The BLS series on labor inputs is based on hours *paid for* rather than *at work* and therefore includes paid vacations and sick leave. Conceptually it would be more appropriate to use a measure of hours of work but the necessary data are not now available. In order to help rectify this problem, BLS started a survey in 1981 which will make it possible in the future to adjust the hours measure to a more appropriate one, hours at work.[23]

Prior to the new survey, the BLS used two sources of information in order to experiment with possible adjustments of hours paid to obtain an hours-at-work measure. One source, which was mainly used internally, employed estimates on leave practices and tenure of employees to calculate vacation time. These estimates were used to compute ratios of hours at work to hours paid in the private nonfarm business and manufacturing sectors during the years 1952–66. The other source of information was a biennial survey conducted by the Bureau of Labor Statistics between 1968 and 1977.[24] In this survey, annual measures of both hours at work and hours paid were collected for office and nonoffice workers in the private nonfarm business and manufacturing sectors.

Table 15 shows average annual rates of growth of the ratio of hours at work to hours paid for selected years based on the 1981 survey findings and estimates from the two earlier sources. The estimates for all employees in private business show that the ratio decreased by 0.1 percent per year between 1952 and 1977. Thus, adjusting the BLS measure of hours paid to an hours-at-work concept would reduce the average annual rate of growth of labor inputs by 0.1 percent per year during that 15-year period and, consequently, raise the annual rate of growth of multifactor productivity by somewhat less than 0.1 percent.[25] The average annual rate of decline in the ratio was 0.2 percent in 1972–77 compared with 0.1 percent during 1952–72, which suggests that the decline in hours at work relative to hours paid contributed to the falloff in the BLS *measured* productivity growth, but only minimally.

Table 15. Rates of growth in the ratio of hours at work to hours paid, private nonfarm business and manufacturing sectors, selected periods, 1952–81

(Percent per year, compounded)

Employee group and period	Private nonfarm business	Manufacturing
All employees:		
1952–77	−0.1	−0.2
1952–72	−0.1	−0.1
1972–77	−0.2	−0.3
Production workers:		
1968–81	(1)	−0.2
1968–72	(1)	−0.2
1972–81	(1)	−0.2

[1]Not available.

SOURCES: 1952–66, unpublished BLS study; 1968–77, Employer Expenditures for Employee Compensation Survey; 1981, Hours Worked Survey (covers production and nonsupervisory workers only).

The estimate for manufacturing suggests that the effects of the increase in hours paid relative to hours at work on measured multifactor productivity growth in that sector are somewhat larger than for private nonfarm business but still quite small. For all employees in manufacturing, the annual rate of decline between 1952 and 1977 in the ratio of hours at work to hours paid averaged 0.2 percent, so that the annual growth rate of multifactor productivity in manufacturing would be increased by somewhat more than 0.1 percentage point if it were adjusted to an hours-at-work concept of labor inputs.

The evidence on the measured contribution to the falloff in the productivity growth rate is unclear: The estimates for production workers which are based on the new BLS survey data for 1981 indicate that the rate of decline in the ratio of hours at work to hours paid remained constant (0.2 percent per year) between 1968 and 1981 and therefore did not affect the measured falloff in productivity during the 1970's. The estimates for all employees, however, show a possible 0.1 percentage point difference in the contribution to the falloff. In any case, to the extent that the declining ratio of hours at work to hours paid was a contributing factor to the measured slowdown, its effects were small.

Summary

This chapter reviewed several of the many factors that have influenced the movements in the BLS measure of multifactor productivity since 1948. While these have helped to explain a part of the longer term annual growth rate and its falloff after 1973, the part left unexplained remains large.

(Continued)

American Economic Review, May 1983, pp. 215–18.

[23]The new survey, conducted annually, collects both quarterly and annual data on hours at work and hours paid for production and nonsupervisory workers. Approximately 4,000 establishments are surveyed, representing the private nonagricultural business sector of the U.S. economy. Adjustments are calculated for the major groups (1-digit SIC) and for the 2-digit industries within the manufacturing sector. The data collected refer to the previous year. Most of the data are tabulated from payroll records. Findings from the initial survey in 1981 indicate that the measures are reliable and consistent with prior expectations. Estimates of hours at work will also be available in the future on a quarterly basis.

[24]Employer Expenditures for Employee Compensation Survey. These series have not been published but are discussed in "Report of the BLS Task Force on Hours Worked" (Bureau of Labor Statistics, March 1976).

[25]The contribution of the decline in the ratio to multifactor productivity growth is measured by multiplying the annual rate of decline by labor's share of total output (0.65).

Between 1948 and 1981, multifactor productivity in the private business sector grew at an average rate of 1.5 percent per year. During this period, intersectoral shifts of labor, particularly from the farm to the nonfarm sector, contributed 0.1 percentage point to the productivity growth rate. Based on Denison's estimates, changes in the composition of the work force, mainly from increased education per worker, contributed an additional 0.4 percentage point. Available information suggests that there was only a small difference in the rate of capacity utilization and that it probably had no significant effect on the long-term growth rate. Judging from Griliches' estimates for the mid-1960's and 1970s's, R&D may have contributed about 0.2 percentage point to the annual growth rate in multifactor productivity during the period. The sparse data available relating hours at work to hours paid show that the use of hours paid rather than the more appropriate hours-at-work concept in the BLS measure of hours of all persons reduced the measured productivity growth rate by 0.1 percentage point. Adding the influences of these five sources indicates that, together, they explain about 0.6 percentage point of the 1.5 percent annual growth rate of multifactor productivity in the private business sector. That is, they explain about 40 percent of the total long-term growth rate; about 60 percent remains unexplained.

The longer term trend was interrupted after 1973: The average annual rate of growth of multifactor productivity in the private business sector declined from 2.0 percent in 1948–73 to 0.1 percent in 1973–81, a falloff of 1.9 percent per year. The shift of workers out of farming into the nonfarm sector had virtually come to an end by 1965, and this contributed 0.2 percentage point to the productivity slowdown from the earlier to the later periods. Changes in the work force occurred at about the same rate in the two periods and therefore had no effect on the falloff. The slowdown in the growth of R&D during the 1970's contributed only to a small degree to the productivity falloff, possibly only about 0.1 percentage point. Using hours paid rather than hours at work in measuring total hours of all persons could have contributed another 0.1 percentage point to the measured productivity slowdown. Adding the effects of these four sources indicates that, together, they contributed about 0.4 percentage point—or about 20 percent—to the 1.9 percent per year slowdown in multifactor productivity in private business. Unfortunately, data are not available for measuring changes in capacity utilization for the private business sector. However, the analysis of the manufacturing sector strongly suggests that changes in the rates of capacity utilization could account for a significant fraction of the unexplained portion of the productivity slowdown in private business. But, even with this additional adjustment, the percentage left unexplained would probably still be large.[26]

[26]For analyses of other possible sources contributing to the productivity slowdown besides those discussed in this chapter, see Edward F. Denison, ''The Interruption of Productivity Growth in the United States,'' *Economic Journal*, Vol. 93, March 1983, pp. 1–22; and Kendrick, ''Survey of the Factors Contributing to the Decline in U.S. Productivity Growth.''

Appendix A. The Multifactor Productivity Model

The new measures of multifactor productivity presented in this bulletin not only extend the scope of productivity analysis by the inclusion of more than one factor but also incorporate a number of recently developed measurement techniques. Many theoretical difficulties in the measurement of aggregate inputs and of productivity growth have been addressed over the last 20 years. As a result, fewer restrictive assumptions are needed in order to measure and aggregate inputs. Now much more general (flexible) functions relating inputs have been developed. Furthermore, index numbers based on discrete data on prices and quantities of the inputs and output of production have been shown to be consistent with these more flexible aggregation functions.

Although econometric methods can be used to identify the structure of production, index numbers enjoy several advantages for measuring productivity. Index numbers avoid the errors inherent in a stochastic specification on a limited sample size. Estimates of productivity based on index numbers provide reliable and timely estimates of productivity change.

This appendix describes in detail how the new measures of multifactor productivity are constructed and how they relate to the older measures of output per hour. The appendixes that follow provide detailed descriptions of the separate factors: Output, capital input, and labor input (hours).

A multifactor productivity measure is similar to a single-factor productivity measure in that it is computed as the ratio of output to input. In the case of the multifactor measure, the input is an index of several factors. In this bulletin, multifactor productivity is defined as value-added output per unit of combined labor and capital input. Real output is a function of the quantities of real capital and real labor inputs used and the technological structure. Output is measured as net of its intermediate inputs. It is the sum of the industries' outputs which are delivered to final demand or, as conventionally stated, the aggregate value added. In accordance with this measure of output, only the primary inputs, labor and capital, are measured and included in the framework. Thus both output and input measures are net of interindustry flows of goods and services. In the BLS series on multifactor productivity, labor is measured as total hours, and capital is measured as the value of services rendered by the stock of capital.[1] The general framework for the measurement of multifactor productivity comes directly from the economic theory of production.[2] In this approach, a production function is postulated as follows:

$$Q(t) = A(t)f[K(t),L(t)] \qquad (A.1)$$

where:

$Q(t)$ = real output,

$K(t)$ = real capital input,

$L(t)$ = real labor input,

$A(t)$ = index of (neutral) technological progress or multifactor productivity.

Taking the logarithmic differential of equation (A.1) with respect to time yields:

$$\dot{Q}/Q = \dot{A}/A + s_k \dot{K}/K + s_l \dot{L}/L. \qquad (A.2)$$

The dot notation refers to the change in the factor over time; hence, $\dot{Q}/Q$ represents the growth rate of output. Similarly, $\dot{K}/K$ is the growth rate of capital and $\dot{L}/L$ is the growth rate of labor. The weights, s_k and s_l, are the output elasticities of the factor inputs. Assuming competitive factor markets and constant returns to scale, the weights equal the relative cost shares of the individual factors in total cost (income):[3]

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[1] See appendixes B, C, and D for detailed explanations and measures of output, capital input, and labor input, respectively

[2] The methodology described in this appendix can be easily extended to different measures of output and to additional factor inputs.

[3] If the function does not exhibit constant returns to scale, $\dot{A}/A$ will reflect both scale effects and technological change. See Michael Denny, Melvyn Fuss, and Leonard Waverman, "The Measurement and Interpretation of Total Factor Productivity in Regulated Industries, with an Application to Canadian Telecommunications," in *Productivity Measurement in Regulated Industries*, Thomas C. Cowing and Rodney E. Stevenson, eds. (New York, Academic Press, 1981).

$$s_k = \frac{p_k K(t)}{p_k K(t) + p_l L(t)}$$

$$s_l = \frac{p_l L(t)}{p_k K(t) + p_l L(t)}$$

$$s_l + s_k = 1$$

$$p_k K(t) + p_l L(t) = \text{current-dollar output} = p_q Q(t).$$

where:

p_k = price of capital services (the rental price)

p_l = price of labor (hourly compensation)

p_q = price of output (the value-added deflator).

Equation (A.2) is the basic measurement relationship for multifactor productivity growth. It expresses the growth in output as equal to a weighted average of the growth in capital and labor inputs plus the growth in multifactor productivity ($\dot{A}/A$). Or, after rearranging terms, the growth rate of multifactor productivity ($\dot{A}/A$) can be measured as the growth rate of the ratio of output to inputs.[4] Hence A(t), productivity in time (t), is:

$$A(t) = Q(t)/I(t) \qquad (A.3)$$

where I(t) is the aggregate index of inputs. This index is computed using discrete annual estimates of prices and quantities. It is the weighted average of the growth rates of the separate inputs. For each time period, the change in I is calculated as:

$$\ln (I(t)/I(t-1)) = w_{kt} \ln (K(t)/K(t-1)) + w_{lt} \ln (L(t)/L(t-1)) \qquad (A.4)$$

where the weights are averages of the relative cost shares of the input factor for the given and previous year:[5]

$$w_{kt} = \frac{s_{k\,t} + s_{k\,t-1}}{2} \qquad (A.5)$$

$$w_{lt} = \frac{s_{l\,t} + s_{l\,t-1}}{2} \qquad (A.6)$$

The index I(t) is a Tornquist index, which is consistent with a "translog" production function.[6] The advantage of the general translog form over the more commonly used Cobb-Douglas function (which is a special case of the translog) is that it has fewer restrictive properties. In particular, the translog function allows the elasticities of substitution among inputs to vary as input proportions vary whereas the Cobb-Douglas does not. This generally is a major improvement over index forms which use constant-base-year-weighted index numbers. This improvement amounts to recognizing that input factor prices and quantities observed in a given year are most relevant for computing weights in that year. Constant weights mean relative use of inputs is held constant even if there are significant price changes in the factor inputs. For example, if the price of capital were to increase sharply relative to labor costs, enterprises would be likely to begin using relatively more labor (work more hours, or work more shifts) and relatively less capital (possibly by reducing investment expansion plans). In this scenario, two changes take place: The relative price of capital increases, and the relative quantity used decreases. The two changes have opposite effects on cost shares or weights. When base-year weights are used, only the quantity change is reflected; in Tornquist weights, both changes are included.

Turning to the relationship between the traditional measure of output per hour and multifactor productivity, it can be shown that the rate of growth of output per hour can be separated into the rate of growth of multifactor productivity and the contribution of changes in capital services per hour. Subtracting the growth in labor input ($\dot{L}/L$) from both sides of equation (A.2) and some further algebraic manipulation yields the following equation:

$$\dot{Q}/Q - \dot{L}/L = \dot{A}/A + s_k (\dot{K}/K - \dot{L}/L). \qquad (A.7)$$

The left side of equation (A.7) is the rate of change of the ratio (Q/L), output per hour; the right side of the equation is the sum of multifactor productivity growth ($\dot{A}/A$) and capital's share times the rate of change of the ratio of capital services to hours (i.e., the contribution of changes in the capital-labor ratio). This is the relationship that is used to analyze the changes in output per hour in chapter III.

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[4] See Charles R. Hulten, "Divisia Index Numbers," *Econometrics*, Vol. 41, No. 6, 1973, pp. 1017–25; and Marcel K. Richter, "Invariance Axioms and Economic Indexes," *Econometrics*, Vol. 34, No. 4, 1966, pp. 739–55.

[5] The weights for a Tornquist index are defined as arithmetic averages of the cost shares. The geometric average is used for computational convenience. Numeric differences between these methods are slight and considered insignificant.

[6] This consistency is shown by W.E. Diewert, "Exact and Superlative Index Numbers," *Journal of Econometrics*, May 1976, pp. 115–45. The translog production function was formulated by L. R. Christensen, D. W. Jorgenson, and L.J. Lau, "Transcendental Logarithmic Production Frontiers," *Review of Economics and Statistics*, February 1973, pp. 28–45.

Appendix B. Real Output Measures: Methods and Sources

This appendix describes the methodology and data sources employed in preparing the real output series for the BLS measures of productivity presented in this bulletin. These include output measures for the business, nonfarm business, and manufacturing sectors which are used in the more familiar measures of output per hour of all persons. The output measures used in the multifactor productivity indexes are for the private business sector and exclude the output of government enterprises. Real output for the farm sector is also measured; it is subtracted from the business output totals in order to obtain the output measures for the nonfarm business sector.

The measures of real output employed in the BLS productivity indexes are derived from data on gross national product (GNP) published in the National Income and Product Accounts (NIPA) by the Bureau of Economic Analysis (BEA), U.S. Department of Commerce. Several important components of the gross national product measures are excluded in order to obtain indexes of output which are appropriate for measuring productivity. This appendix explains the reasons for these exclusions. It also describes the concepts and methods underlying the measures for the farm and manufacturing sectors.

Business sector

The business sector is the largest aggregate for which productivity measures are presented in this bulletin. Output of the sector can be briefly described as all activities of for-profit business establishments engaged in production in the United States. It is based on concepts underlying the NIPA measures of GNP.[1]

Table B–1 shows the relationship of the BEA measure of GNP and the BLS measure of private business output in 1981 (1972 prices). The value of output in the private business sector accounted for 76 percent of GNP. The 24 percent of GNP not included comprised general government; output of the "rest of the world"; output of household workers and of nonprofit institutions; output imputed to the housing services of owner-occupied housing; and the statistical discrepancy.[2]

These components of GNP were excluded from the BLS measure of output used for productivity measurement

Table B–1. Relationship between gross national product and the BLS measure of private business sector gross product, 1981

Item	Amount (billions of 1972 dollars)	Percent
Total: Gross national product[1]	$1,502.6	100
Excluded from BLS private business gross product:	349.6	23
Output originating in:		
General government[2]	156.0	10
Owner-occupied housing[3]	100.2	7
Rest of the world[2]	25.4	2
Households and institutions[2 4]	52.1	3
Statistical discrepancy[2]	−0.9	([5])
Government enterprises[6]	22.0	1
Equals: BLS private business gross product	1,147.3	76
Value of output deflated by output price indexes	1,133.2	75
Nonresidential structures[1]	51.6	4
Services furnished without payment by financial intermediaries, except life insurance carriers[7]	19.6	1
Other	1,062.0	71
Value of output deflated by index of wage rates and materials prices	14.1	1
Personal consumption expenditures (part)[8]	12.9	1
Producers' durable equipment (part)[9]	1.3	([5])

[1] Table 1.2 in *Survey of Current Business*, July 1982.
[2] Table 1.6 in *Survey of Current Business*, July 1982.
[3] Table 1.21 in *Survey of Current Business*, July 1982, and unpublished detail for farms. Comprises $98.9 billion of nonfarm and $1.3 billion of farm housing.
[4] Includes unpublished BEA measures of nonprofit real estate rental value.
[5] Less than 0.5 percent.
[6] Table 6.2 in *Survey of Current Business*, July 1982.
[7] Table 2.5 in *Survey of Current Business*, July 1982.
[8] Estimate provided by the Bureau of Economic Analysis, U.S. Department of Commerce, from unpublished detail underlying table 2.5 in *Survey of Current Business*, July 1982. Comprises life insurance and commercial and vocational schools.
[9] Table 5.7 in *Survey of Current Business*, July 1982. Comprises ships and boats.

[1] For a description of the concepts, methodology, and sources of data underlying the NIPA, see Carol S. Carson and George Jaszi, "The National Income and Product Accounts of the United States: An Overview," *Survey of Current Business*, Vol. 61, February 1981, pp. 22–34; "Revised Estimates of the National Income and Product Accounts," *Survey of Current Business*, Vol. 62, July 1982, and *National Income, 1954 Edition: A Supplement to the Survey of Current Business*.

[2] The statistical discrepancy is the difference between GNP and the charges against GNP. It arises because GNP and the charges against GNP are estimated independently, and each is subject to measurement errors.

because (1) no adequate corresponding labor or capital input measure can be developed for these components of the NIPA or (2) the gross product measures for the component are based on labor inputs, implying constant output per unit of labor input.

The specific reasons for excluding each of these components will be discussed in turn. Before doing so, it is important to note that only about 1 percent of private business output (measured in 1972 prices)—the remainder after the exclusions from GNP—was based on real output measured by deflating current-dollar output by an index of labor and materials inputs.[3] This clearly does not represent a serious problem in measuring real output for the private business or private nonfarm business sector.

The output of general government has been excluded since the BLS measures of output per hour were first introduced in 1959. This exclusion is due to the manner in which constant-dollar real output is measured in the NIPA. In the accounts, general government output is derived by moving base-year compensation by changes in total hours of government employees adjusted for changes in grade level. This virtually assumes that productivity remains constant, since changes in output are essentially proportional to changes in hours. Although this is not the only area in the national accounts where, for lack of data, output change is equated with labor input change, it is by far the largest single sector where this occurs. In addition, the proportion of employment accounted for by government (including military) has increased significantly since 1950.

BLS excludes the rest-of-the-world sector because there are no corresponding labor or capital input data. The current value of output of the rest-of-the-world sector is equal to payments to factors (labor and capital) abroad owned by U.S. residents, less payments to factors in the United States owned by foreigners. Hence, a dividend paid to a foreigner is a negative entry and a wage received by an American employee in a foreign country is a positive entry. Since it is not possible to identify domestic labor or capital inputs associated with this output, the rest-of-the-world sector is excluded.

Output imputed to owner-occupied dwellings is also excluded from the aggregate productivity measure because there is no measure available for the labor input of homeowners. In the NIPA, an imputation is made for the rental value of owner-occupied homes. This imputation treats homeownership as a business providing housing services which are sold to the homeowner in his capacity as tenant. The output of this service is estimated as the amount for which owner-occupied homes could be rented, less maintenance, insurance, and like expenses of the homeowner. Since no comparable labor input data are available for the activity of homeownership, the product of owner-occupied homes is excluded from the output estimates for productivity purposes.

The output measure for private households is excluded because real output in this sector is measured by labor input. The household industry refers to domestic employees, and current value of output is measured in the NIPA by the compensation of domestic employees. Real output is measured by deflating this compensation by the Consumer Price Index for housekeeping and home maintenance services, which is essentially an index of hourly compensation. This assumes that output per employee is constant over time.

Nonprofit institutions are also excluded because real output is measured essentially by labor inputs. Current value of output is measured using employee compensation. The BEA method of deflation used for nonprofit organizations is somewhat more complex than that used for private households. Nevertheless, real output of nonprofit institutions is essentially measured by deflating the employee compensation series by an index of compensation per full-time-equivalent employee. These measures have serious limitations for productivity measurement, and this sector is consequently excluded from the private business sector.

The ''statistical discrepancy'' is the difference between GNP estimates measured from the product and income (''charges against GNP'') sides of the accounts.

Government enterprises—the U.S. Postal Service, other Federal enterprises such as the Tennessee Valley Authority, and State and local enterprises such as State-run liquor stores—are excluded for two reasons. First, it would be especially difficult to measure capital inputs in this sector because in the NIPA, structures and durable equipment used by these enterprises are treated as final sales to general government, rather than as investments of the enterprises. Government enterprises thus show no capital cost associated with plant and equipment. The second reason concerns the measurement of income from capital (i.e., property income). In these enterprises, capital and labor are combined in multifactor productivity measurement, and this requires the use of labor and capital income shares as weights. Satisfactory data are available on compensation of employees; however, the data on income from capital are unsuitable because these enterprises are subsidized by the government and the pricing of output reflects these subsidies. Thus, estimating property income as the residual of value of output minus labor compensation would seriously understate capital's share of output.

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[3] Table B–1 shows that, within the 76 percent of GNP used to calculate the BLS measure of private business output (in 1972 prices), only 1 percentage point was accounted for by ''output measured by labor input.'' That is, it accounted for only 1.3 percent of private business output (.01 divided by .76).

Farm sector

The measure of output used in the BLS index of multifactor productivity for private nonfarm business is obtained by subtracting real output of the farm sector from private business real output. The measure for real farm output is the BEA estimate of "gross farm product" in constant (1972) prices.[4] BEA, in turn, bases its measures on estimates of farm income and expenses prepared by the U.S. Department of Agriculture (USDA) employing data collected by the USDA and benchmarked periodically to statistics from the Census of Agriculture.

The BEA measure of gross farm product is derived by the "double-deflation" value-added procedure. Using this method, the current values of output and purchases of intermediate goods and services by the industry are first deflated by appropriate price deflators. The deflated figures for purchased goods and services are then subtracted from the deflated value of output; the residual is industry product originating (value added) in constant prices.[5]

BEA farm output includes cash receipts from farm marketings, net Commodity Credit Corporation loans, rental value of farm dwellings, home consumption of farm products, other farm income, and changes in inventories. Receipts from farm marketing of crops and livestock are obtained by summing monthly estimates based on quantities sold and market prices, or, in the case of poultry and dairy products, directly from production reports. Sales of approximately 150 items are covered, accounting for 90 percent of farm income. All sales of crops are covered, including seed and feed sold to other farmers; livestock sold to other farms in the same State are excluded from both sales and expenses. Farm sales of forest products are included in the crop totals.

Constant-dollar estimates of farm output are obtained by deflating each of the current-dollar components separately. Constant-dollar farm marketings are obtained for the following categories of farm products: Food and feed grains; oil bearing crops; tobacco; cotton; vegetables; potatoes, sweet potatoes, and beans; fruit; other crops; meat animals; dairy products; poultry and eggs; wool; and other livestock. Deflators are aggregated from 150 "prices received by farmers" collected by the USDA. Food and fuel consumed on farms are deflated by the same USDA prices received by farms or appropriate NIPA personal consumption expenditure deflators.

Intermediate goods and services purchased include all production costs incurred by the farm operator, such as feed, seed, fertilizer, contract labor, machine hire, and rent paid to nonoperator landlords. Estimates of most expenses are based on information from USDA surveys of farm production expenses. Constant-dollar estimates are prepared by BEA by separately deflating 13 expense components, using appropriate indexes from among the "prices paid by farmers" published by USDA.

The difference between BEA farm output and intermediate purchased goods and services is gross farm product in current dollars, the NIPA measure of farm value added, or the contribution of the farm sector to current-dollar GNP. Equivalently, on the income side, gross farm product comprises factor incomes (employee compensation, net interest, noncorporate income, corporate profits) plus nonfactor costs (capital consumption allowances, indirect business taxes), less subsidies to farmers. These components of GNP originating on farms are estimated concurrently with the farm output and purchases data.

Similarly, the difference between the deflated value of farm output and the deflated cost of intermediate goods and services purchased is equal to real farm gross product, or the contribution of the farm sector to real GNP.

Manufacturing sector

The computation of real output in manufacturing follows the double-deflation method discussed above for the farm sector.[6] In the NIPA, the output measures for manufacturing are prepared in two steps: (1) A deflator is obtained by dividing Census current-dollar value added by constant-dollar value added; and (2) this deflator is applied to the BEA measure of gross product originating in manufacturing. Current-dollar value added in the first stage is derived from data from the Censuses and Annual Surveys of Manufactures on the value of manufacturing production, less the cost of materials, less the estimated value of business service inputs. Constant-dollar value added is the deflated value of production, less the deflated value of material inputs, less an estimate of the deflated value of service inputs.

The BEA gross product data to which the value-added deflators are applied are the sum of factor and nonfactor charges, compiled independently for 2-digit Standard Industrial Classification (SIC) industries in the NIPA. The underlying deflation of the value of output and of material inputs is done at the most detailed level of industry possible.

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[4]For a description of the method and sources used by BEA to measure gross farm product in the NIPA, see Shelby W. Herman, "The Farm Sector," *Survey of Current Business,* Vol. 58, November 1978, pp. 18–26. The annual figures in current and constant prices appear in tables 1.18 and 1.19, respectively, in the July issues of the *Survey*.

[5]Conceptually, the sum of gross product originating (value added) for all industries is equal to GNP. This is so in both current and constant dollars. However, in practice, the equality in constant prices may not hold because of errors of measurement.

[6]BLS used the same method for manufacturing in the 1950's. See *Trends in Output per Man-Hour and Man-Hours per Unit of Output—Manufacturing, 1939–53,* Report 100 (Bureau of Labor Statistics, 1955).

Manufacturing output. Value of shipments and changes in inventories are prepared for 4-digit SIC industries in manufacturing.[7] These data have been collected since 1949 and published in the benchmark Censuses and Annual Surveys of Manufactures in generally the same form. There have been periodic revisions to the SIC affecting both product and industry classifications. Large revisions took place in 1958 and 1972, causing some establishments in 4-digit Census industries to be moved across 2-digit lines. In most cases, the effect of these classification revisions at the 2-digit industry level is small or even trivial.

The deflation of value of shipments and changes in inventories is done by BEA using the BLS product class indexes, which are groupings of highly detailed producer price indexes into the "5-digit" product categories reported in the Annual Survey of Manufactures. This tabulation of prices was published in the late 1950's as part of the Census of Manufactures for benchmarking purposes, and it has been maintained ever since.[8] About 54 percent of the product classes in manufacturing are covered by BLS product price indexes. Another 38 percent are covered by related BLS price indexes. Price series for most of the remainder are constructed as weighted averages of indexes of material input and labor costs.

Cost of materials, containers, and supplies. The current cost of materials inputs is collected by the Census Bureau and published in the Annual Survey of Manufactures and the Census of Manufactures. All purchased materials are included, with the exception of those bought for resale without further processing. All fuels and office supplies are included; items treated as capital investment are excluded.

The current cost of materials is deflated to obtain the real quantity of materials inputs for double-deflation purposes. Deflators are constructed by BEA using BLS producer prices (mainly the 5-digit product-class deflators) and weights based on the BEA input-output tables of the U.S. economy for the years 1947, 1958, 1963, 1967, and 1972. The tables provide a complete list of material inputs for each industry for those years, from which weights are computed for the aggregation of materials prices. Weights are interpolated between tables; for years after the most recent input-output table, weights remain constant.

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[7]The classification of products and establishments in the BLS productivity program follows the scheme established by the Office of Management and Budget in its *Standard Industrial Classification Manual*, 1972 edition. Under this system, related products or services are grouped together in categories denoted by a code of up to 7 digits, depending on the breadth of the category. Thus, a 7-digit code is assigned to a relatively narrowly specified group of products, and a 2-digit code to a broad area such as fabricated metal products (SIC 34). Every establishment reporting data to the Census Bureau or the BLS is assigned the 4-digit code in which its most important product, in terms of value of shipments, falls.

[8]These indexes were constructed jointly by the Board of Governors of the Federal Reserve System, the Bureau of Labor Statistics, and the Bureau of the Census. They were published in *United States Census of Manufactures, 1954, Vol. IV: Indexes of Production* (Bureau of the Census, 1958).

Appendix C. Capital Input and Capital and Labor Shares

Capital input, defined as the services from physical assets, is measured for each of three subsectors of the U.S. private business sector—manufacturing, farm, and nonfarm-nonmanufacturing. These measures are then aggregated to the three published sectors: Private business, private nonfarm business, and manufacturing. This appendix presents a detailed discussion of how capital is measured and of how the capital and labor cost shares used to weight the respective input measures are determined.

The capital measures are constructed in three major stages. First, stocks are estimated for 47 type of assets; this is discussed in section I. Second, rental prices are estimated for each type of stock. Third, assets are aggregated using shares based on rental prices. These last two stages in developing the aggregate measures are described in section II. Section III discusses the method used to measure capital and labor income shares. Section IV examines the capital input measures and capital and labor shares of income. Section V reports on the sensitivity of capital input and multifactor productivity measures to the inclusion of inventories and land and to alternative ''efficiency'' functions. The final section summarizes the discussion and concludes with the detailed tables of capital input measures by major type of asset for the private business, private nonfarm business, and manufacturing sectors. Table C–1 provides a convenient guide and summary of the procedures used to generate the BLS capital measures (steps 1–7) as well as of the additional work needed to measure multifactor productivity (steps 8–10).

Table C–1. Summary of methods and data sources used to measure capital and multifactor productivity—Continued

Step	Data item obtained or constructed	Methods used and detail in which step is performed	Data source
1. Obtain real investment data for depreciable assets	Investment in: a. equipment b. structures c. rental residential capital	a. 20 asset types b. 14 asset types c. 9 asset types	a.–c. National Income and Product Accounts (NIPA)[1]
2. Allocate investment data to major sectors	Investment by asset type by sector (manufacturing, farm, nonfarm-nonmanufacturing)	a. asset detail allocated using: b. sectoral investment totals proportional to c. historical data cross-classified by asset detail and sector	a. step 1 b. NIPA c. NIPA
3. Determine age/efficiency functions for each type of asset	Weights reflecting the declining services of an asset type cohort as it ages	A hyperbolic form using: a. an average service life estimate b. normal distribution of discards c. a shape determined using empirical evidence	a. NIPA b. NIPA c. Hulten and Wykoff[2]
4. Perform vintage aggregation	Real stocks of depreciable assets by type by sector	Perpetual inventory method: Real historical investments weighted by age/efficiency functions	a. steps 2 and 3
5. Measure nondepreciable assets	a. stock of inventories b. stock of farm land c. stock of land in manufacturing and nonfarm-nonmanufacturing	a. by stage of processing in manufacturing b. regional services weighted using rental prices c. proportional to structures using benchmark land estimate	a. NIPA b. U.S. Department of Agriculture c. Manvel[3]
6. Construct rental prices	Implicit rental value of the services of a unit of each type of asset in each sector	a. rental price formula estimated using data on capital stocks and data on payments to capital	a. Christensen and Jorgenson[4]; steps 4 and 5; NIPA
7. Aggregate assets	Measure of real capital input in each sector	Tornquist index of asset capital stocks using rental prices to determine weights	a. steps 4, 5, and 6

See footnotes at end of table.

Table C-1. Summary of methods and data sources used to measure capital and multifactor productivity—Continued

Step	Data item obtained or constructed	Methods used and detail in which step is performed	Data source
8. Construct cost shares	Shares of labor and capital inputs in the value of each sector's output	Based on: a. employees' labor compensation b. corporate capital payments and c. proprietors' income allocated to labor and capital using d. employee compensation per hour and e. corporate rate of return to capital	a.–c. NIPA d. BLS e. based on step 6
9. Combine inputs	a.–c. measures of combined labor and capital input by sector (manufacturing, farm, nonfarm-nonmanufacturing) d. measures of combined input for private business, nonfarm business	Tornquist index of: a. labor and b. capital in each sector using c. cost shares as weights d. Tornquist index of combined input across sectors using factor shares in value of output	a. BLS b. step 7 c. step 8 d. shares based on NIPA
10. Compute multifactor productivity	Reported for private business, nonfarm business, manufacturing	Ratio of: a. output to b. input	a. NIPA b. step 9

[1]Bureau of Economic Analysis.

[2]Shares were reconciled to functions reported in Charles R. Hulten and Frank C. Wykoff, "The Estimation of Economic Depreciation Using Vintage Asset Prices: An Application of the Box-Cox Power Transformation," *Journal of Econometrics*, 1981, pp. 367– 96; and in C. R. Hulten and F. C. Wykoff, "The Measurement of Economic Depreciation," in C. R. Hulten, ed., *Depreciation, Inflation and the Taxation of Income from Capital* (Washington, The Urban Institute Press, 1981), pp. 81–125.

[3]Benchmarks based on estimates from Allan D. Manvel, "Trends in the Value of Real Estate and Land, 1956–1966," in *Three Land Research Studies* (Washington, National Commission on Urban Problems, 1966).

[4]Formula used to measure rental prices derived by Laurits R. Christensen and Dale W. Jorgenson, "The Measurement of U.S. Real Capital Input, 1929–1967," *Review of Income and Wealth*, Vol. 15, No. 4, 1969, pp. 293–320.

I. Measurement of Capital Stocks by Asset Type

This section is concerned with the framework used to construct the BLS capital measures.[1] A central concept in this framework is that of the "productive" capital stock, or the stock measured in efficiency units. Conceptually, the productive stock represents the amount of new investment which would be required to produce the same capital *services* actually produced by existing assets of all vintages. Thus, total current services from assets of all vintages are proportional to the productive stock. It is this measure of capital stock which is directly associated with productivity. The measurement of the productive stock involves vintage aggregation, which requires historical data on real investment and an "age/efficiency" function that describes the pattern of services that capital goods supply as they age.

In addition, this section discusses the measurement of the "wealth" stock of physical capital, or the stock measured in terms of the market price of used assets. Conceptually, the wealth stock represents the present value of all future services embodied in existing assets. Unlike the productive stock, the wealth stock does not directly influence productivity but indicates the current market value of all new and used capital goods. The wealth stock is needed to estimate depreciation, which is used in measuring the implicit rental prices for capital.

Vintage aggregation

Each type of stock is computed by the perpetual inventory method. The stock at the end of a period is equal to a weighted sum of all past investment, where the weights are the asset's efficiency (defined below) as of a given age.

Mathematically, the *productive* stock K_t, at the end of the period t is given by:

$$K_t = \Sigma_{\tau = t}^{\infty} s_{\tau - t} I_{2t - \tau} \qquad (C.1)$$

where I_t is investment in period t
and s_t is the efficiency function.

[1]The model used to measure capital stock was developed in Robert E. Hall, "Technical Change and Capital from the Point of View of the Dual," *Review of Economic Studies*, January 1968, pp. 35–46. The model was used empirically in Laurits R. Christensen and Dale W. Jorgenson, "The Measurement of U.S. Real Capital Input, 1929–1967," *Review of Income and Wealth*, Vol. 15, 1969, pp. 292–320. An extensive discussion of this topic, together with references to the literature, may be found in W.E. Diewert, "Aggregation Problems in the Measurement of Capital," in Dan Usher, ed., *The Measurement of Capital* (Chicago, The University Press, 1980) pp. 433–528.

Table C–2. Illustration of a perpetual inventory calculation for a fictional type of asset

Item	Age/efficiency function	1971	1972	1973	1974	1975	1976	1977	1978
Gross new investment		100	120	150	200	100	200	220	250
Contribution of goods of a given age to year-end stock:									
Age 0	1.0	100*	120	150	200	100	200	220	250
1	.9		90*	108	135	180	90	180	198
2	.7			70*	84	105	140	70	140
3	.4				40*	48	60	80	40
4	.1					10*	12	15	20
5	.0						0*	0	0
Year-end stock (weighted sum of past investments)						443	502	565	648
Change in stock since previous year							59	63	83
Equals gross investment							200	220	250
Minus efficiency losses of all vintages							141	157	167

The efficiency function is a schedule which indicates the quantity of services provided by an asset of a given age relative to a new asset of the same type. This function is generally assigned a value of 1.00 when the asset is new and declines as the asset ages, eventually approaching or reaching zero. Consequently, investments in the more distant past contribute less to current output.

Illustration of perpetual inventory method. Table C–2 illustrates the perpetual inventory method for a hypothetical asset with a 5-year service life. The cells of the matrix of contributions to the capital stock are calculated as the product of two values. The first value is the age/efficiency function for an asset of the given age (column 1). The second is the gross investment made the given number of years ago. The contribution of a given year's investment to the stock can be tracked through the successive years as it ages. This is done by following a diagonal downward and to the right. One example is marked with asterisks.

The total stock in a given year is equal to the sum of contributions from past investments. It changes from year to year to reflect new gross investments net of accruing efficiency losses. *These losses cannot be calculated without knowing the distribution of past investments.* Only in the case of geometric decay are they equal to a constant percentage of the stock.

In order to measure the first year's stocks, it is necessary to collect historical investment data extending back as long as the life of the asset. The U.S. Commerce Department's estimates of investment go back as far as 1820 for some types of structures.

The same procedures are used for each of 43 types of depreciable assets in order to obtain the BLS measures of capital. Each type of asset has a different efficiency function depending on its expected life and on whether it is a structure or a type of equipment. The year-end stocks are then averaged with the previous year-end stock to estimate the services contributed by a given type of asset during the year. Average stocks of different asset types are then aggregated using a Tornquist index. In this procedure, rental prices are used to construct the weights for assets of different types by different sectors.

Age/efficiency function

In general, the relationship between the economic efficiency of an asset and its age is very complex and depends on the particular type of asset as well as on a host of other factors such as the level of economic activity, relative input prices, interest rates, and technological developments. To further complicate matters, it is very difficult if not impossible to "observe" or directly measure quantity of capital services. The standard practice among economists is to represent the pattern of services as a capital good ages by using an efficiency function as defined above. This pattern of services is proportional to the rental income, in constant prices, which the good is capable of generating.

Use of an efficiency function involves strong assumptions. First, the quantity of capital services from a particular type of asset is assumed to be a function of its age.[2] Second, the pattern does not respond to any factors other than age, remaining fixed over time. In view of these restrictive assumptions, the validity of using an efficiency function to represent capital services remains a major issue, particularly as it relates to the applicability of microeconomic assumptions to aggregate data.

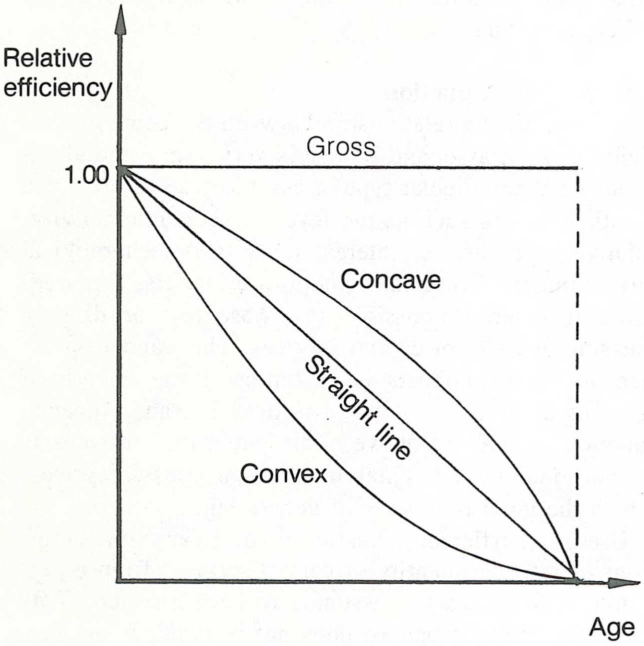
Several general forms have been employed by researchers. These are illustrated in chart C–1. Use of the gross stock or "one hoss shay" form assumes that the asset exhibits no loss of services until it suddenly expires. A light bulb is perhaps the best example of this. The three other forms are "net" of some loss of services during their lives. The straight-line form exhibits the same loss of services each year. The concave form exhibits gradual losses early in the life of an asset, and more rapid losses as it ages. The convex form exhibits

[2]For a criticism of this approach, see Martin S. Feldstein and Michael Rothschild, "Towards an Economic Theory of Replacement Investment," *Econometrica*, May 1964, pp. 393–424.

rapid early service losses followed by more gradual losses of the remaining efficiency.

Practitioners have adopted a wide variety of solutions to the problem of selecting an appropriate efficiency function. John Kendrick prefers a gross stock form.[3] A concave form is used by Edward Denison[4] and was used in the past by BLS.[5] Dale Jorgenson and his associates have used the convex geometric form.[6] Edward Miller points out that, since obsolescence as well as deterioration must be removed as an asset ages, a straight-line or even convex form may be best.[7] Both Kendrick's and Denison's work is based on capital stock data computed by BEA.

Chart C-1.
General forms of an efficiency function



Several attempts have been made to address the efficiency function issue by observing used asset prices.[8] A relationship is postulated between the efficiency of a used asset and its market price relative to a new asset. In a dynamic model where the firm minimizes costs over all time periods, the market price of an asset will equal the discounted (rental) value of the stream of future services that the asset embodies. This duality between efficiency and price also determines the relationship between the (assumed) form of the efficiency function and the pattern of prices as the asset ages. Thus, observations of used asset prices may be employed indirectly to infer the form of the efficiency function.[9]

The most intensive empirical study of used asset prices done to date is by Hulten and Wykoff.[10] In a 5-year project recently completed for the Treasury Department, Hulten and Wykoff collected extensive data on prices of used assets and fitted them econometrically to various mathematical forms. Their published findings make use of a very general function, the "Box-Cox" function. Thus, rather than assume either a convex or concave form, they employed a function which can be either convex or concave depending on the sample data. The gross, straight-line, and geometric shapes are special cases of the Box-Cox function so that it can be used to statistically test each of these cases. Hulten and Wykoff reject each of these three special forms of the age/price function. Their results, in particular, rule out the geometric form and the one hoss shay (gross capital stock) for most types of assets. They did, however, find that the typical age/price profile of an asset was convex.

In order to obtain a summary measure of depreciation for each type of asset, Hulten and Wykoff fitted "best geometric approximations" (BGA) to their Box-Cox estimated prices. These were determined by regressing the logarithms of the Box-Cox estimated prices against age and time. The results indicated no consistent trend in

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3John W. Kendrick, *The Formation and Stocks of Total Capital,* National Bureau of Economic Research (New York, Columbia University Press, 1976).

4Edward F. Denison, *Accounting for Slower Economic Growth: The United States in the 1970's* (Washington, The Brookings Institution, 1979).

5*Capital Stocks for Input-Output Industries: Methods and Data*, Bulletin 2034 (Bureau of Labor Statistics, 1979).

6See, for example, Barbara M. Fraumeni and Dale W. Jorgenson, "The Role of Capital in U.S. Economic Growth, 1948–1976," in George von Furstenberg, ed., *Capital, Efficiency and Growth* (Cambridge, Mass., Ballinger Publishing Co., 1980), pp. 9–250.

7Edward M. Miller, *Capital Aggregation for Productivity Measurement and Other Purposes,* Working Paper No. 34 (Houston, Jesse H. Jones Graduate School of Administration, Rice University, May 1983).

8For a discussion of problems in empirically determining the form of the efficiency function, see Michael J. Harper, "The Measurement of Productive Capital Stock, Capital Wealth, and Capital Services," Working Paper No. 128, (Bureau of Labor Statistics, 1982).

9This is perhaps most simply illustrated in the special case of the geometric form. If the efficiency function is a geometric form (i.e., a convex form in which efficiency declines by the same percent each year), then the price pattern is also geometric so that depreciation (i.e., the rate of decline in price) occurs at the same constant rate as the efficiency loss. This "self duality" property is possessed only by the geometric form.

10The work is presented in Charles R. Hulten and Frank C. Wykoff, "The Estimation of Economic Depreciation Using Vintage Asset Prices: An Application of the Box-Cox Power Transformation," *Journal of Econometrics,* 1981, pp. 367–96; and in C.R. Hulten and F.C. Wykoff, "The Measurement of Economic Depreciation," in C.R. Hulten, ed., *Depreciation, Inflation and the Taxation of Income from Capital* (Washington, The Urban Institute Press, 1981), pp. 81–125.

the age/price profile over time; the age coefficients represent an estimate of the average rate of depreciation.

After carefully considering the alternatives, BLS decided to use a concave efficiency form (slow decline during the earlier years), and to determine its shape using available empirical evidence. The assumption of a concave form was settled on because of the cursory observation that many capital assets do not tend to decay rapidly during their intital years. In addition, members of the BLS Business Research Advisory Council canvassed their organizations and reported similar experiences with the capital assets owned by the firms they represent.

The mathematical form used for the age/efficiency relationship is the hyperbolic function:

$$s_t = (L - t) / (L - \beta t) \quad O<t<L$$
$$s_t = O \quad t>L \qquad (C.2)$$

where s_t is the relative efficiency of a t-year-old asset
L is the service life
t is the age of the asset
and β is the parameter allowing the shape of the curve to vary.

In this formula, a value of β equal to zero corresponds to a straight-line efficiency pattern, while a value of β equal to one is consistent with the one hoss shay. The mean service lives, L, are the BEA estimates shown in table C–3. In experiments described shortly, it was determined that the best statistical fit to the Hulten-Wykoff data using a hyperbolic functional form resulted in an efficiency function which declines initially at one-half the straight-line depreciation rate for equipment, and at one-fourth the straight-line rate for structures.

Since formula (C.2) is applied to broad types of assets, each of which represents a variety of capital goods, a distribution of lives was assumed. This was done by constructing a ''cohort'' efficiency function which is a weighted average of efficiency functions calculated using formulas (C.2) and various specific ages. The weights are determined by a discard density function. Chart C–2 illustrates a cohort efficiency function for an assumed average life of L years with a truncated normally distributed density function of retirement ages ranging from 0.5 to 1.5 times L.

Chart C-2.

Cohort efficiency function for gross stocks with a truncated normally distributed discard function

(Two standard deviations correspond to one-half of the mean service life, L)

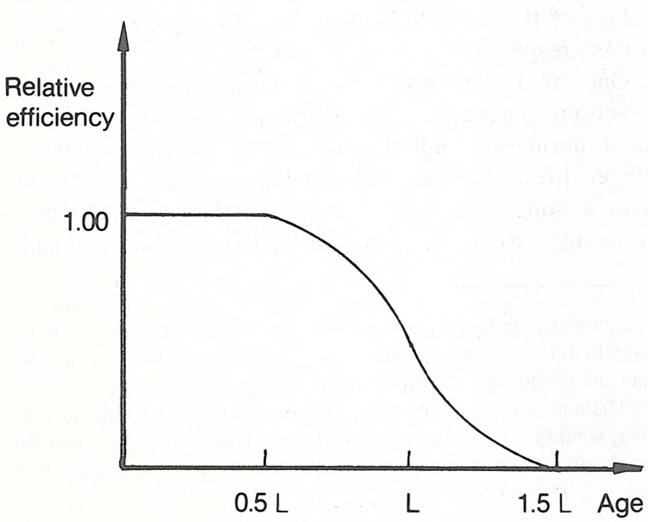

Table C–3. Types of assets and service life assumptions

Type of asset	Life (in years)
Nonresidential equipment	
Furniture and fixtures	15
Fabricated metal products	18
Engines and turbines	21
Tractors	8
Agricultural machinery (except tractors)	17
Construction machinery (except tractors)	9
Mining and oilfield machinery	10
Metalworking machinery	16
Special industry machinery	16
General industrial, including materials handling equipment	14
Office, computing, and accounting machinery	8
Service industry machinery	10
Electrical machinery	14
Trucks, buses, and truck trailers	9
Autos	10
Aircraft	16
Ships and boats	22
Railroad equipment	25
Instruments	11
Other equipment	11
Nonresidential structures	
Industrial buildings	27
Commercial buildings	36
Religious buildings	48
Educational buildings	48
Hospital and institutional buildings	48
Other nonfarm nonresidential buildings	31
Railroad structures	51
Telephone and telegraph structures	27
Electric light and power structures	30
Gas structures	30
Other public utility structures	26
Farm nonresidential buildings	38
Petroleum, gas, and other mineral drilling and exploration	16
All other private nonresidential structures	31
Residential assets	
Tenant-occupied nonfarm:	
1- to 4-unit structures (additions)	80
1- to 4-unit structures (new)	40
Structures of 5 units or more (new)	65
Structures of 5 units or more (additions)	32
Mobile homes	16
Residential equipment	11
Tenant-occupied farm:	
1- to 4-unit structures (new)	80
1- to 4-unit structures (additions)	40
Mobile homes	16

BLS selected a somewhat flatter truncated normal distribution ranging from 0.02 to 1.98 times L. (Two standard deviations correspond to 0.98 times the mean service life.) Thus, formula (C.2) was computed repeatedly for each asset type, with L varying between 0.02 and 1.98 times the mean service life. The results of these computations were then added together, weighted by a discrete approximation to the normal density function, to produce a cohort efficiency function. The value 0.98 was chosen in order to conform to the empirical observation by Hulten and Wykoff that assets are occasionally found which are considerably older than the BEA-estimated average service lives and also to take account of the fact that a few assets are accidentally destroyed when new.

The final step in estimating the cohort age/efficiency function was to obtain estimates of β, the parameter that determines the shape of the hyperbolic function (C.2). As previously noted, these were estimated using the Hulten and Wykoff fitted Box-Cox price functions. Specifically, the following equation was used to generate dual price functions for selected values of β:[11]

$$p_t = \frac{\sum_{\tau=t}^{\infty} s_\tau^* (1-r)^{\tau-t}}{\sum_{\tau=0}^{\infty} s_\tau^* (1-r)^{\tau}} \qquad (C.3)$$

where p_t is the price of a t-year-old asset relative to a new one

s_t* is the cohort efficiency function

and r is real discount rate assumed to be .04.

The values of β selected were 0.0 (straight-line efficiency loss), 0.25, 0.5, 0.75, and 1.0 (one hoss shay). The three intermediate forms correspond to increasing degrees of concavity for the hyperbolic function (C.2). The simulated dual price functions for each of the five values of β was compared with the Hulten-Wykoff fitted Box-Cox function. The estimate of β chosen was the one that resulted in the best fit.[12] This same procedure was used to estimate values of β for four different types of structures and one type of equipment (tractors).

In addition, efficiency functions were compared directly to a proxy for the services provided by trucks. This proxy was constructed from the Census Bureau's *Truck Inventory and Use Survey* (1977). Estimates of the total number of trucks and total truck miles were obtained for each of 12 model years. Miles per year were then computed for each model year as a proxy for the services provided by the fleet of trucks still in service by age. Finally, this miles per year variable was adjusted for discards (mean service life of 8 years, normally distributed between 0 and 16 years) and compared directly to the presumed efficiency pattern using the same error comparison statistics described in footnote 12. These steps were repeated for light and heavy trucks.[13]

Table C-4. Weighted sum of differences between hyperbolic efficiency patterns and simulated data

Type of asset	Value of β parameter[1]				
	0.00 (straight line)	0.25	0.5	0.75	1.00 (one hoss shay)
Structures					
Retail (prices)[2]	0.956	0.803	0.630	0.432	0.268*
Offices (prices)	.394	.324	.258	.217*	.421
Warehouses (prices)	.229	.203	.189*	.210	.483
Factories (prices)	1.173	1.001	.796	.538	.139*
Equipment					
Tractors (prices)	.523	.467	.399	.309	.133*
Light trucks (efficiency)[2]	.224	.139	.058	.003*	.155
Heavy trucks (efficiency)	.023	.008*	.011	.063	.359

*=closest fitting β parameter.

[1]Statistics presented are the weighted sum of squared differences between the dual to the presumed hyperbolic function and the fitted Box-Cox function. Weights are the Box-Cox function itself.

[2]Price comparisons were done between price functions which were dual to assumed hyperbolic forms and simulated price series using price parameters based on Hulten and Wykoff's fitted Box-Cox price functions. Efficiency comparisons were done directly between efficiency patterns and a miles per year proxy for truck efficiency. See text for complete descriptions of data and comparison statistics.

The comparison statistics for the seven sets of trials are shown in table C-4. The lowest value, indicating the best fit, is marked with an asterisk for each trial. For structures, one hoss shay was best in two cases, while relatively high β values of 0.50 and 0.75 were best in one case each. For equipment, one comparison (tractors) was made on the basis of price, while two comparisons (trucks) were made directly between efficiency functions. One hoss shay was best for tractors, while β values of 0.75 and 0.25 were best for light and heavy trucks, respectively.

One of Hulten-Wykoff's important results is that structures depreciate very slowly compared to equipment during the initial years, even considering their longer lifetime. The trial comparisons are consistent with a somewhat higher β value (slower decay) for structures. Also, as indicated earlier, the Hulten and

[11]This is simply a discount formula, which assumes that the purchase price of an asset equals the real discounted rental value of the stream of all future services that the asset will generate.

[12]Two statistics were used to determine the best fit between the simulated dual price functions and the Hulten and Wykoff Box-Cox prices: (1) the coefficient of determination; and (2) a weighted sum of squared errors between the dual and Box-Cox prices where the weights are the heights of the Box-Cox function so as to put more weight on the newer assets which, in fact, constitute a greater portion of the stock for each type of asset.

[13]Other factors, particularly maintenance costs and type of driving, would also affect relative efficiency. However, adjustments for such factors would be difficult to construct accurately even if data were available.

Wykoff tests reject the one-hoss-shay specifications. On the basis of these considerations and the experiments reported above, the estimate of β used in the age/efficiency functions for structures is 0.75; and the estimate of β used in age/efficiency functions for equipment is 0.50.

To summarize, the age/efficiency function used in the BLS measures of the productive stock of capital by asset type is the hyperbolic form. The choice of this form is a "prior" based on cursory observations and informal discussions with businessmen. The average lives used are those estimated by BEA. The estimates of the β parameters for structures (0.75) and equipment (0.50) are consistent with the Hulten-Wykoff evidence on used asset prices.[14]

Real gross investment

Besides an efficiency function, the other element required to perform vintage aggregation in equation (C.1) is historical data on real gross investment. This section discusses the methods and sources of data used to measure the stocks of depreciable assets and to estimate the price deflators for new durable goods. It also describes the sources and methods used to construct stocks of inventories and land.

Estimates of investment are available from BEA for a variety of asset categories, in both historical and constant dollars. Constant-dollar investment is based on historical-dollar investment deflated by BEA in detailed categories. Equipment is deflated principally by using BLS Producer Price Indexes (PPI). Structures are deflated by indexes of residential prices, highway construction prices, and construction cost indexes.[15] Historical-dollar investment estimates are developed at BEA from survey data and are assigned to detailed asset categories using a "capital flows table" based on U.S. Census Bureau surveys of industry.

Annual investment from BEA is available by major sector, by tenure group, by legal form of organization, and by asset class. Major sectors include manufacturing, farm, and nonfarm-nonmanufacturing. The calculations described below are conducted separately for each of these three sectors. The tenure grouping applies only to residential capital and refers to whether housing is owner- or tenant-occupied. BLS measures exclude all owner-occupied housing, but include tenant-occupied housing, since private business sector output includes rental housing. Legal form of organization comprises several subdivisions. The major split is between corporate and noncorporate. The noncorporate sector, in turn, can be divided into sole proprietorships, partnerships, tax-exempt cooperatives, and nonprofit institutions. The BLS measures do not use these detailed subdivisions. With respect to investment data, the only separate subgroups by legal form of organization is nonprofit institutions, since these are excluded from the business sector data. However, BEA net stock figures for the corporate and noncorporate sectors are used to estimate corporate factors for the rental price computations.

The final and most detailed breakout available from BEA is by type of asset. The major BEA asset types are equipment and structures. Since residential capital is almost entirely structures, aggregates are presented for three major groups of capital assets: Nonresidential equipment, nonresidential structures, and total residential capital. This procedure makes it possible to show nonresidential fixed capital for those interested in the effect of excluding residential capital (see tables C–8 and C–9 in the last section of this appendix).

Each major asset category is divided into more specific types. Table C–3 in the previous section lists the 20 types of equipment, 14 types of structures, and 9 types of residential capital. BLS applies the perpetual inventory calculation separately for each type of asset. Performing the calculation in greater asset detail allows the stock measures to reflect changes in the distribution of service lives. Lack of such detail can bias the stock measures through two mechanisms—through changes in the asset composition of current-dollar investment and through differences in the growth rates of the prices of the various assets. In the present study, such asset detail is maintained not only during the perpetual inventory calculation, but also during rental price computation, allowing use of asset-specific estimates of the effects of tax laws, depreciation, and price inflation.

BEA has estimated investment data as far back as possible (in some cases as early as 1820) to ensure that the perpetual inventory has been through one full life cycle by 1948, the initial year for which the BLS measures capital. This is necessary to avoid measurement bias that would tend to overstate the rate of growth of capital.

The following subsections specify which nonresidential and residential investment data are used in the BLS application of the perpetual inventory method. Several steps are taken to ensure that detailed investment data are fully consistent with the most recent totals available from BEA.

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[14]It is also important to note that the "best geometric averages" (BGA's) computed by Hulten and Wykoff are equally consistent with their data. That is, given the current state of knowledge, there is no empirical basis for choosing between the hyperbolic and geometric forms. The choice is then up to the researcher, and, clearly, different researchers have different preferences. The concluding section of this appendix reports on a sensitivity analysis based on alternative assumptions about the form of the age/efficiency function for the measurement of the growth of both the capital stock and multifactor productivity.

[15]A more detailed discussion is presented in the *Survey of Current Business*, August 1974.

Nonresidential investment. BEA has provided historical data by detailed asset type cross-classified by major sector. This includes constant-dollar investment by asset type for residential and nonresidential equipment and structures in three sectors: Farming, manufacturing, and nonfarm-nonmanufacturing. This historical detail is revised each time there is a benchmark revision of the National Income and Product Accounts (NIPA). Updates and revisions for more aggregate totals are available from BEA annually. The annual updates include constant-dollar and current-dollar investment data by asset type and sector. The BEA updates also include revisions to all series used to estimate corporate shares. In general, the cross-classified data are adjusted at BLS to correspond to revisions in the asset type investment totals using the biproportional matrix model (or "RAS" model).[16] Furthermore, updates of the cross-classified detail are estimated from asset type and sectoral totals for the new year by applying the biproportional model to a matrix starting with the cross-classified data for the most recent year available. Essentially, it is a method of creating a matrix which is consistent with known row and column sums and as consistent as possible with cross-classified data from a second source.

After constant-dollar investment is allocated by asset type and sector, current-dollar investment is estimated for each category. This is done by multiplying the constant-dollar figures by price deflators. Separate deflators are estimated for each asset type, but are assumed to be the same in all sectors for a given asset type. In effect, the output deflator for the producing industry is assumed to apply to all purchasers.

Deflators are estimated in two steps. First, current-dollar investment figures supplied by BEA are divided by corresponding constant-dollar figures for each asset type. Second, these initial estimates of the deflators are scaled to equal 1.00 in 1972. This step is necessary because some adjustments done by BEA affect 1972 current-dollar investment and constant-dollar investment differently. These adjustments reflect transfers of property, including business purchases of secondhand government assets, sales by business to foreigners, transfer of residential capital from farm to nonfarm status, purchases of residential capital by government for demolition, sales of passenger cars to the public by rental firms, and conversions of residential capital from tenant- to owner-occupied status. These adjustments are reflected in the BLS constant-dollar investment series.

Within nonfarm-nonmanufacturing, an adjustment is made to remove nonprofit institutions from investment estimates for equipment, structures, and residential capital. These are removed from capital in order to be consistent with the output and labor data in the private business sector; output measures available from the NIPA are based largely on labor inputs.

Specific asset categories likely to contain nonprofit assets are isolated based on information from BEA. For structures, nonprofit investment is assumed to be a fixed percentage of investment in four asset categories: Religious buildings (100 percent), educational buildings (98 percent), hospitals (95 percent), and other nonfarm nonresidential buildings (30 percent). Since initial BLS estimates of total nonprofit investment based on these percentages overestimate the BEA figure, the difference is reallocated among educational buildings, hospitals, and nonfarm nonresidential buildings to ensure consistency with the most recent BEA total.

For equipment, total investment by nonprofit institutions reported by BEA is allocated to four equipment asset types: Furniture and fixtures, office machinery, trucks, and autos. In this study, the allocation is made in such a way that, when nonprofit institutions have been subtracted from these four categories, the relative proportions of the four asset types are unaffected.

Residential investment. Since private business sector output excludes owner-occupied housing, the only residential investment series included in BLS capital measures are tenant-occupied farm and nonfarm residential housing. Tenant-occupied nonfarm investment is assigned to the nonfarm-nonmanufacturing sector; farm investment, to the farm sector.

Constant-dollar residential nonfarm investment in structures is available for five types of assets (table C–3). Equipment is available for only a single asset type. Constant-dollar residential farm investment is available for structures for three asset types. Since current-dollar totals were not available for the five types of tenant-occupied nonfarm structures, deflators are determined for total nonfarm residential investment. These deflators are then multiplied by each of the five asset classes to determine estimates of current-dollar investment for the five categories.

Although stock estimates exist for tenant-occupied farm structures in recent years, BEA has assumed new investment in this category to be zero since 1967 to ensure that their stock estimates decline as quickly as their benchmark data indicate. Proxies are therefore needed for BLS to calculate deflators for the three asset types included in this category. Prices for new and additional tenant-occupied 1- to 4-unit farm structures are assumed to equal the ratio of current- to constant-dollar owner-occupied farm structures of this size. Prices for tenant-occupied farm mobile homes are assumed to equal the ratio of current- to constant-dollar investment in owner-occupied farm mobile homes.

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[16]The biproportional model is discussed by Michael Bacharach in "Estimating Non-Negative Matrices from Marginal Data," *International Economic Review*, 1965, No. 6, pp. 294–310.

A number of additional adjustments to residential investment data are made before the perpetual inventory method is applied. These include a reallocation involving nonfarm structures after 1970, an adjustment to make less detailed updates conform with the categories for which historical data are maintained, and, finally, the extraction of nonprofit investment from residential assets.

First, an adjustment is made by BEA to represent the large number of condominium conversions during the 1970's. The adjustment—to total constant-dollar investment for nonfarm residential structures—has the effect of gradually moving condominiums from new tenant-occupied to new owner-occupied nonfarm structures during the years after 1970. During the years 1970–74, this reallocation is not reflected in the data by asset type cross-classified by major sector. The reallocation for condominiums is applied entirely to new tenant-occupied nonfarm structures of 5 units or more.

Smaller differences between the BLS sum of investment for the five structure asset types and the structures total received from BEA occur for years where condominiums are not an issue. As in the case of nonresidential capital, these small differences occur because the more detailed data are obtained from a listing to which revisions are not frequently made. In the BLS measures, the most recent totals are imposed, and any discrepancy between totals and detail is distributed proportionally to the five categories of detail. Also, totals are updated to include new years before complete detail is available. Again, totals for updated years are allocated in proportion to detail from the most recent year for which it is available.

Finally, investment in residential capital by nonprofit institutions is removed. Total residential nonprofit figures are available from BEA, but asset detail for this sector is not. Such investment occurs mainly in three asset types: New 1- to 4-unit structures, new structures of 5 units or more, and nonhousekeeping structures (a residential asset type not included in the private business sector). All nonhousekeeping structures are considered nonprofit institutions. Therefore, they are subtracted from total residential nonprofit constant-dollar investment. The amount left over is then removed proportionally from the other two asset types.

Inventories. Estimates of inventories in current and constant dollars are published in the *Survey of Current Business* for the three major sectors. Since the published figures are end-of-period estimates, and since the concept of a productive input would be the average level during the year, an average of the end-of-quarter figures is computed in order to better approximate the average annual level. For the manufacturing sector, data are available from BEA on inventories by stage of processing. The stages are materials and supplies, work in process, and finished goods. Within manufacturing, BLS works with the disaggregate BEA inventories to reflect this detail. The rationale for including all types of inventories in a capital measure is that all represent a cost and all can contribute to the orderliness of the production process.

Land. Estimation of the quantity and rental price of land is important to the measurement of growth in multifactor productivity for the private business sector, especially for the farm and nonfarm-nonmanufacturing sectors. Besides the fact that land is a productive input in its own right, it is important to assign it a share in capital income when determining the rates of return and rental prices for all capital inputs. Unfortunately, the measurement of land poses several difficulties, the most serious of which is the scarcity of data for the manufacturing and nonfarm-nonmanufacturing sectors. Fortunately, land represents a smaller share of capital here than in the farm sector, where data are available.

In the farm sector, data published by the U.S. Department of Agriculture include land in farms (acreage), total current-dollar value of land plus buildings, and total current-dollar value of buildings alone. BLS calculates a benchmark total value of land by subtracting the total value of buildings from the total value of land and buildings in 1972. This benchmark is extrapolated using an unpublished index of the quantity of land services provided by V. Eldon Ball of the Department of Agriculture. Ball derived this as a Tornquist index of regional land estimates using rental prices to determine weights. Rental prices are estimated from actual rental transactions observed in the various regions. These measures are ideal from a conceptual viewpoint, because they are aggregated considering the apparent differences in efficiency of land in different regions. Also, the weights used in this aggregation are based on direct observation of the rental market for land rather than on the implicit methods used for most rental prices in this study.

In order to estimate land in manufacturing and nonfarm-nonmanufacturing, structures are multiplied by a land-structures ratio. The first step toward deriving an estimate of real land stocks for the manufacturing and nonfarm-nonmanufacturing sectors is to relate estimates of structures by Manvel to the BLS data on capital efficiency and wealth.[17] This is done by using 1966 ratios of land to structure values based on Manvel's work and applying these ratios to the BLS estimates of the value of structures in 1966 results in benchmark land estimates.

[17]Use was made of data published in Allan D. Manvel, "Trends in the Value of Real Estate and Land, 1956–1966," *Three Land Research Studies* (Washington, National Commission on Urban Problems, 1968).

Manvel's land estimates are not used directly because the structures estimate on which they are based does not conform to BLS structures. This is due to differences in sectoral definitions and in the technique used by Manvel to arrive at his benchmark. By employing a ratio, Manvel's work is used to extrapolate from the BLS benchmark. The current-dollar stock of structures in 1966 consistent with BLS data is calculated by reflating detailed constant (1972) dollar stocks of structures (in value or wealth terms) by each asset's investment price deflator in 1966. Current- and constant-dollar asset stocks are then aggregated for each of three categories: Manufacturing, nonresidential nonfarm-nonmanufacturing, and residential nonfarm-nonmanufacturing. Benchmarks for 1966 for land are then calculated by multiplying these 1966 structure values by ratios of land to structures. Each category's stock of structures is multiplied by a corresponding 1966 ratio. The ratio for manufacturing is based on Manvel's estimates of industrial structures and land; for nonresidential nonmanufacturing, on his estimates of total commercial and industrial property; and for residential land, on his estimates of urban residential property.

The linking of current- and constant-dollar land value growth rates to structures requires selection of an appropriate structures concept for extrapolation. Although stocks net of depreciation (losses in value) are used to benchmark land quantities, gross stocks of structures (i.e., based on one-hoss-shay efficiency patterns) are used to extrapolate them. Also, reflated gross stocks are used to extrapolate estimates of the current-dollar value of land. This tends to remove a bias that could be introduced into land quantity and value estimates from the depreciation of structures. In effect, BLS assumes that the real value of land cannot be a function of the depreciation of the building standing on it. The extrapolation is done separately for manufacturing and for the residential and nonresidential business parts of nonfarm-nonmanufacturing, since separate benchmarks are available for each. These are then aggregated to represent a total nonfarm-nonmanufacturing stock of land. Deflators are then calculated by dividing the current-dollar land stock by the constant-dollar stock for the manufacturing and nonfarm-nonmanufacturing sectors.

Wealth stock

The discussion up to this point has been mainly concerned with the computation of the "productive" capital stock by asset type. The productive stock, as shown by equation (C.1), is based on the asset's age/efficiency function and is the appropriate concept of capital inputs to use for productivity measurement.

This section describes the computation of the "wealth" stock, which is based on the age/price function, equation (C.3). The wealth stock represents the sum of money (in base-period prices) which could be generated by selling all vintages of an asset at prevailing real prices. The wealth stock is used to estimate depreciation, which is used in computing rental prices.

The wealth stock, like the productive stock, is computed by the perpetual inventory method; it too adds past investments using weights which decline with the age of the asset. However, in the case of the wealth stock, the weights are based on the age/price function rather than the age/efficiency function (C.2). Mathematically, the vintage aggregation equation used to compute the wealth stock is:

$$W_t = \Sigma_{\tau = t}^{\infty} p_{\tau - t} I_{2t - \tau} \qquad (C.4)$$

where p_t is the asset's age/price function
and I_t is investment in period t.

The age/price series for p_t are obtained from equation (C.3). The real gross investment data for the I_t are the same as those used to construct the productive capital stock; the sources and methods for these data are described above.

Equation (C.4) shows that the wealth stock measures the value represented by all existing assets. It thus represents the present value of all future service embodied in existing capital assets because of the relationship between efficiency and price discussed earlier.[18] The decline in the wealth stock from one period to the next, before adding in new investment, is a measure of depreciation. Depreciation represents the amount of money in the current period needed to maintain the stock of wealth at its current level. This information is used to estimate rental prices discussed below.

Timing of investment and output

Both the productive and the wealth stocks are year-end estimates and include all changes occurring during the year, such as new investment, accruing efficiency loss, and depreciation. These changes do not, in general, have their full impact on output during the year in question. For example, an increment of investment put in place on January 1 may have an impact on output during the entire year. Investment put in place July 1 can only affect output during the second half of the year, and December investment can contribute almost nothing to current-year output. Since the investment figures received from BEA count investment at the time it is finished and ready to use, it seems reasonable to count about half of a given year's new investment, efficiency loss, and depreciation towards the annual average meas-

[18]The wealth stock and the productive stock coincide in the special case where the age/efficiency function is one of geometric decay.

ures of stocks. Therefore, a half-year convention is used in the BLS measures. A given year's output is matched to the arithmetic mean of the current year-end stock and the year-end stock for the previous year. Thus, capital services are assumed proportional to the *annual average* productive stock of a given asset. These averages are used to compute the Tornquist index of real capital input (appendix E) and the index of real factor input in the multifactor productivity measures. On the other hand, depreciation during the year is computed from the year-end stocks of wealth in order to reflect the losses of value from the beginning to the end of the year.

As previously indicated, vintage aggregation is done separately for each of the 43 depreciable asset types listed in table C–2. Time series are generated representing the productive stock, the wealth stock, real depreciation, gross new real investment, and the price deflator of new capital goods. Each of these is computed by asset for each of the three major subsectors of the private business sector.

II. Aggregation of Capital Stocks by Asset Type

After the productive capital stock for each type of asset is computed, the next major step is to combine these different stocks in order to obtain the aggregate measures of capital input for the private business, private nonfarm business, and manufacturing sectors. The productive stocks are aggregated by asset type using implicit rental prices as weights. The method and data sources used to construct the rental prices are described below. The Tornquist formula is used for the aggregation; this is defined in appendix F, where it is compared with other methods of aggregation.

Rental price (user cost) of capital

The ''implicit rental price'' or ''user cost'' of capital is based on the neoclassical principle that inputs should be aggregated using weights that reflect their marginal products. The assumption used to formulate the rental price expression is that the purchase price of a capital asset equals the discounted value of the stream of services (and, hence, implicitly the rents) that the asset will provide. Disregarding inflation and taxes, the rental price, c, would be

$$c = p\,(r + d) \tag{C.5}$$

Where p is the price of the asset, r is a rate of return, and d is the rate of depreciation. In terms of equation (C.5), c represents the amount of rent that would have to be charged in order to cover costs of p dollars' worth of an asset. For example, if d = 0.10 and the real interest rate is 0.04, the owner would have to charge $.14 in rent in order to cover expenses on a $1 asset. At the end of a year, he could sell what was originally a $1 asset for $.90 and pay the bank 4 cents interest due, breaking even.

Inflation in the price of new assets and tax laws complicate the derivation of the rental price. Hall and Jorgenson[19] derived the expression:

$$c_t = \frac{(1 - u_t z_t - e_t)\,(p_t r_t + p_t d_t - \Delta p_t)}{1 - u_t} + p_t x_t \tag{C.6}$$

where

- u_t is the corporate income tax rate
- z_t is the present value of $1 of tax depreciation allowances
- e_t is the effective rate of the investment tax credit
- r_t is the nominal rate of return on capital
- d_t is the average rate of economic depreciation
- p_t is the deflator for new capital goods
- Δp_t is revaluation of assets due to inflation in new goods prices
- x_t is the rate of indirect taxes.

The data sources for and derivation of these variables are discussed below. All of the variables on the right side of expression (C.6) except for the rate of return, r_t, are derived from these sources. Before the rental prices are computed, expression (C.6) is used to solve for an implicit rate of return rather than using a market interest rate.[20] Computing the internal rate of return is necessary to empirically implement (C.6) because the rate of capital gain is frequently greater than market interest plus depreciation. The procedure would result in some negative rental prices if the market interest rate were used.

In order to obtain the implicit rate of return, the rental price, c_t, is multiplied by the capital stock, K_t, and this product is set equal to capital (i.e., nonlabor) income reported in the NIPA. The following equation for r_t, the implicit internal rate of return, is derived by substituting c_t from equation (C.6) in the product $c_t\,K_t$:

$$r_t = \frac{Y_t - K_t p_t x_t - K_t\,(p_t d_t - \Delta p_t)\,(1 - u_t z_t - e_t) / (1 - u_t)}{K_t p_t\,(1 - u_t z_t - e_t) / (1 - u_t)} \tag{C.7}$$

where Y_t is capital income and K_t is productive capital stock.

Expression (C.6) is computed separately by BLS for

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[19] Robert E. Hall and Dale W. Jorgenson, ''Tax Policy and Investment Behavior,'' *American Economic Review,* Vol. 57, June 1967, pp. 391–414.

[20] The method used to obtain the implicit rate of return was derived in Christensen and Jorgenson, ''The Measurement of U.S. Real Capital Input.''

each type of asset and r_t is computed jointly for all assets. By solving for r_t, NIPA capital income, Y_t is exactly allocated to capital assets. That is, the rental prices, c_i, are determined by solving for the rate of return such that:

$$Y_t = \Sigma_i \, c_{it} K_{it}. \qquad \text{(C.8)}$$

Hence, $c_{it} K_{it}/K_t$ is the share of capital income allocated to the *ith* asset in year t.[21]

Computation of rental prices for capital requires estimates of capital income and several tax rates. Data on capital income are available in the NIPA. For the corporate sector, a comprehensive set of categories of capital income is available for each major sector—profits, net interest, capital consumption allowances, transfers, indirect business taxes, and inventory valuation adjustments. These components are aggregated to obtain a measure of the current value of corporate capital income.

Data for measuring capital income for noncorporate capital are incomplete. This is because proprietors' income in the NIPA is not differentiated between wage and salary income (labor) and profits (capital income). This is a difficulty not only for estimating noncorporate rental prices, but also for determining noncorporate capital and labor income shares, a problem which is addressed below. Noncorporate rental prices are determined by assuming that they are equal to corporate rental prices for each type of asset. Corporate rental prices are determined after estimating the corporate portion of each type of productive capital asset. These percentage estimates are based on ratios of corporate to total net BEA stocks for equipment, structures, and residential capital in the farm, manufacturing, and nonfarm-nonmanufacturing sectors. The most closely corresponding share is multiplied by the BLS estimate of the total productive stock for an asset type in each year in order to determine the corporate productive stock of the asset. This is the estimate of corporate k_t used in estimating the internal rate of return in equation (C.7).

Deflators are calculated for new investment goods based on the ratio of current- to constant-dollar investment for each asset. The rate of depreciation is the ratio of the real value of depreciation to the real wealth stock. The real value of depreciation equals real investment minus the increase in the wealth stock. The effective rate of indirect taxes is assumed to be equal for all assets, and is defined as total indirect taxes in the sector divided by the total stock of wealth.

Estimates of the effective rate of the investment tax credit for each type of capital for each year are also required. The strategy used by BLS to estimate effective credit rates for each of 21 equipment categories is to consider historical credit laws and to assume a distribution of useful tax lives associated with the average service lives used.[22]

In estimating effective tax credit rates, BLS attempts to account for all the special features of the law, except those related to the profitability tests and carryover rules. Therefore, the rental price formulation is used in such a way as to assume that all marginal investment decisions are made by firms which are operating at a profit for tax purposes. Although this is restrictive, it is preferable to the alternative of using actual allowances claimed, which reflect historical decisions as well as incentives in the current period.

The first step in the procedure is to estimate, for each type of equipment, the percentage of the maximum allowable rate which is applicable.[23] For this purpose, service lives for tax purposes are assumed to be normally distributed about the mean service life, with the distribution cut off before 0.5 times the mean life and after 1.5 times. Although we assume lives are more widely dispersed for the purpose of vintage aggregation, a more truncated distribution of service lives is used for tax purposes. The full amount of the credit is assumed to have been claimed for that portion of the distribution of service lives over 8 years, ⅔ credit for that between 6 and 8 years, and ⅓ credit for lives under 6 years. The procedure is repeated for each asset type for the post-1970 period, when 5 and 7 years are the appropriate cutoffs. Since the smallest mean service life is 8 years, no portion of any of the distributions falls in the range where no credit is allowed (less than 3 years).

Next, these initial estimates are multiplied by the rate of the maximum allowable credit for the year in question. In years where the credit was suspended by Congress for part of the year, estimates are multiplied by the percentage of days in the year in which the credit was in effect. The result is an asset-specific estimate of

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[21] The farm sector is handled somewhat differently with respect to determining the asset shares in capital income. This exception will be discussed together with the handling of farm proprietor's capital-labor income shares at the conclusion of this section of the appendix.

[22] Data on investment tax credits actually claimed are available for corporations by detailed industry group in the U.S. Treasury Department's *Statistics of Income*. The difficulty with this direct source is that actual credits claimed reflect the complexities of the tax laws concerning credits.

The rental price expression is meant to represent the price incentives afforded firms on a marginal decision to buy new capital. Since the direct data reflect complex rules on profits tests and carryovers and carrybacks, the volume of credits tends not to respond proportionally to changes in new investment. Thus, the ratio of the volume of credits taken in a year to nominal new investment is a poor indicator of marginal incentives. For example, in 1970 the credit was totally suspended for new investment, and yet substantial credits were claimed against that year's taxes because of carryovers from earlier years.

[23] The procedure used is similar to the methods used by others, such as Patrick J. Corcoran and Leonard G. Sahling, "The Cost of Capital: How High Is It?" *Federal Reserve Bank of New York Quarterly Review,* 1982, Summer, pp. 23–31.

the marginal incentive associated with the investment tax credit for that year.

The rental price formulation, equation (C.6), also requires an estimate of the present value of $1 of depreciation deductions, z_t. This is the portion of investment expenses which can be recovered in capital consumption allowances after discounting these allowances for nominal interest charges. This value is generally less than 1, since deductions are based on historical purchase prices. This value is generally lower for longer lived assets because the deductions must be more severely discounted.

It is assumed that all firms elected straight-line depreciation prior to 1954, double declining balance with switchover to straight line for 1954–80, and the accelerated capital recovery system (ACRS) beginning in 1981. For each depreciation pattern and for each type of asset, an allowable stream of deductions for $1 of new investment is calculated. This stream is based on the assumed average service lives used for computing capital input and a normally distributed retirement pattern. Then, that stream is discounted using the average long-term bond rate in effect during a given year. Therefore, the estimates of the present value of $1 of depreciation used by BLS vary not only by type of asset but also from year to year as a function of changing interest rates.

Finally, equation (C.6) requires an estimate of the corporate income tax rate, u_i. The traditional way of estimating this rate is to compute the ratio of total corporate profits tax liability to before-tax total profits. Such a rate presumably reflects an aggregate of tax rates actually paid during the year including the effect of those companies which faced losses. In such an approach, no attempt is made to differentiate the effective tax rate by type of asset. The difficulty is that this average tax rate is not conceptually appropriate for the rental price expression. In this expression, the tax rate should reflect the marginal incentives afforded investors in new capital by current tax laws and it should be specific to the type of asset.

BLS follows an approach suggested by Jorgenson and Sullivan.[24] They use the statutory tax rate for their estimate of u_t in equation (C.6)—the marginal rate faced by a profitable firm. Using the rental price formulation, (C.6), they derive an expression for an "effective" rate in terms of the statutory tax rate (u_t), the effective rate of investment credits (e_t), the present value of $1 of depreciation ($z_t$), and the other variables in the rental price expression. Since u_t, e_t, and z_t are distinguished by asset type, this effective rate reflects the asset-specific effects of each of these aspects of the tax law.

Capital costs

The main source of data on capital cost is the NIPA. BEA produces estimates of capital costs, by type of cost, for 2-digit industries. Data collected include capital consumption allowances, profits (before and after taxes), net interest, business transfer payments, and indirect business taxes. Since the work on capital costs is based on the corporate sector, data specific to that sector are collected. Each component is obtained separately for the corporate portions of manufacturing, farm, and nonfarm-nonmanufacturing. The noncorporate sector is excluded from this cost work because detailed noncorporate income data are unavailable. As discussed earlier, noncorporate rental prices are assumed to be equal to corporate rental prices for each specific type of asset in each major sector.

A majority of the series are obtained from information provided by BEA containing the "14 components" of income. From this source, BLS obtains estimates, by 2-digit industry, of corporate capital consumption allowances, corporate profits, total business transfer payments, and indirect business taxes. Using this data, indirect taxes and transfers are allocated to the corporate sector in proportion to corporate shares in the stock of corporate and noncorporate depreciable assets. These shares are based on BEA measures of net capital stock. Capital consumption allowances exclude adjustments. Total net corporate interest and corporate profits tax liability are obtained from table 1.13 in the *Survey of Current Business*. Corporate profits before and after tax by industry are obtained from tables 6.21 and 6.23 of the same publication. Net corporate interest by sector is obtained from the BEA staff.

As discussed earlier, the BEA work on the measurement of capital stock is the source for the gross investment data for the BLS major sector capital measures. Although BLS computes stocks by type of asset for each major sector (manufacturing, farm, and other), it does not do so separately for corporate and noncorporate stocks. Estimates of the corporate breakout are needed, however, to estimate rental prices. Cost data are used as a basis for rental prices in the corporate sector. Noncorporate rental prices are then set equal to corporate rental prices at a disaggregate level. This equality assumption, in effect, excludes from the BLS measures any capital composition adjustment based on legal form of organization. Differences between corporate and noncorporate rental prices could be used as the basis for a significant composition adjustment because the relative size of the noncorporate sector has declined steadily over time. However, the composition adjustment might mistakenly imply that capital input is growing faster than it would if the trend were absent.

Since rental prices must be calculated for the corporate sector alone, estimates of the corporate stock of

[24] In this approach, the rental price expression is used to investigate the effects of inflation, working through the tax system, on investment incentives. See Dale W. Jorgenson, and Martin A. Sullivan, "Inflation and Corporate Capital Recovery," in C. R. Hulten, ed., *Depreciation, Inflation and Taxation of Income from Capital,* pp. 171–237.

each asset type in each sector are required. BEA net stocks are used to derive corporate stocks for each asset. BEA provides corporate stocks broken out by sector and year for equipment, structures, and residential capital. In each sector and in each major asset category (that is, equipment, structures, and residential capital), the ratio of corporate capital stock to total capital stock is computed based on the BEA net stock estimates. Using these ratios, BLS proportionally allocates stock estimates for more detailed asset types to the two legal forms, the corporate and noncorporate sectors.

Aggregation procedure

As indicated in the introduction to this section, the Tornquist procedure is used to combine the capital stock series by asset type described in the previous section using the rental price described in this section to derive weights. The resulting indexes are the BLS-derived aggregate measures of capital service inputs. The capital input index for the private business sector is, in effect, a weighted sum of the percent changes in capital stocks by asset type where the weights are averages of the respective rental prices for the current and past year. The capital input measures for private nonfarm business and manufacturing are similarly aggregated.

Appendix E contains a discussion of the Tornquist index number formula. Capital input indexes by broad class of asset are presented for each of the three major sectors at the end of this appendix.

III. Capital and Labor Income Shares

The other major methodological issue addressed in this appendix concerns the calculation of capital and labor income shares. These shares are used to weight the labor and capital inputs in order to obtain the combined input measure.

Data are available in the NIPA for employee compensation and for corporate capital income. Corporate capital income is defined by BLS to include unadjusted before-tax profits, corporate capital consumption allowances, corporate net interest payments, corporate inventory valuation adjustments, and a portion of indirect business taxes. Corporate capital income is used to determine the corporate rental price for each type of asset as outlined in the previous section. However, the NIPA report only a single figure for proprietors' income, which reflects returns to both labor and capital. Since data are available on hours of proprietors and unpaid family workers, and on noncorporate capital stock, it is possible to develop an implicit capital-labor split of proprietors' income by assuming either that proprietors and unpaid family workers earn the same wage as employees or that corporate and noncorporate capital yield the same rate of return.

Unfortunately, the two methods of imputation applied together generally overestimate the NIPA measures of proprietors' income. Rather than select one imputation over the other, the two methods are initially employed simultaneously, and the results are reconciled at a later stage.

First, an imputation is made for noncorporate income by assigning proprietors and unpaid family workers the same average wage received by paid employees, and then adding to that an imputation of capital income by assigning noncorporate capital the same rental price as corporate capital.[25] This imputation is compared to noncorporate income in the NIPA. (Noncorporate income includes proprietors' income, noncorporate capital consumption allowances, and a portion of indirect business taxes.) The imputation is adjusted to equal the reported noncorporate income by multiplying the wages of proprietors and unpaid family workers and the noncorporate rate of return by a single scalar which *equates* the imputed and NIPA totals. Thus, noncorporate wages and the rate of return to capital are scaled back proportionally to determine proprietors' capital and labor shares. It should be noted that the scalar is applied only to the rate of return on capital, not to the entire rental price. Thus, the noncorporate rates of economic depreciation, asset revaluation, and indirect taxes are held equal to the corporate sector.

The rationale for this treatment is that these other elements are exogenous for the self-employed. The self-employed can willingly accept lower wages and returns to their capital in exchange for the greater degree of independence—or for some other reason. However, their preference is unlikely to affect factors like economic depreciation or inflation. Tables C–5 through C–7 illustrate the effects of this procedure.

Two exceptions are made to the methods outlined above for allocating capital income in the farm sector. During the period studied, farm land prices consistently increased faster than the deflators for other capital inputs. In terms of the rental price equation (C.6), the capital gains (Δp) on land frequently exceeded the rate of return, which was presumed equal for all assets. To maintain the assumption that the rates of return were equal for all asset types would imply that land frequently had a negative rental price and a negative income share. Such a situation makes little sense and would invalidate a Tornquist index based on these "shares."

[25]For the purposes of this analysis, the income of employees of proprietors is excluded from noncorporate income. The assumption made implies that, while proprietors can accept a lower wage and rate of return than corporations, they do not have the same control over the wages of their employees. Therefore, employees of proprietors are assumed to have the same wage as other employees and no further adjustment to their wage is made. Adjustment is made only by changing proprietors' wages and the rate of return to noncorporate capital.

This difficulty with high capital gains on farm land is well known. Doll and Widdows[26] point out that farmers have often made a large portion of their income in the form of capital gains on land which occur at rates in excess of the general inflation rate. Sometimes the effect is so large that farmers with little equity in their land are forced to take out increasing mortgages against the ever larger land values to maintain a positive cash flow.

Because of this situation, capital-labor income shares and asset type income shares cannot be reasonably estimated based on the model described above. Instead, shares of capital assets in farm capital income are estimated as follows. First, rental prices for each type of asset are assigned using an assumed real rate of return (4 percent) plus the asset's depreciation rate. Then, an estimate of total farm capital income is computed as a sum of terms, each term being the productive stock of an asset type times its assigned rental price. Next, each asset is assigned a share in total capital income based on the share of its term in the sum. Finally, these assigned shares are used to weight the various productive stocks to compute real capital input as a Tornquist index of the asset type stocks.

Since these assigned prices are not controlled to any income or cost estimate, the estimate of capital income derived in this way is not used in determining farm capital and labor income shares. Instead, total capital income is assumed to equal corporate capital income in the NIPA plus an estimate of noncorporate capital income. The noncorporate capital income estimate is assumed equal to the noncorporate productive stock times the ratio of the corporate capital income to the corporate productive stock.

Farm proprietors' wages are initially computed by equating them with employees' wages in the same manner as for the nonfarm sectors. Wages are also imputed to unpaid family workers at the same rate on the assumption that they receive compensation for their services in unmeasured forms. This imputation is compared to total NIPA noncorporate income after noncorporate capital income is subtracted. The imputation is adjusted by multiplying the wages of proprietors and unpaid family workers by a scalar which equates the imputed and BEA-reported totals.

IV. Examination of the Measures

Measures of total capital input and multifactor productivity were presented in the main body of this bulletin. In this section, capital measures are given in more detail. The three sectors for which measures are presented are private business, private nonfarm business, and manufacturing. These reflect calculations which were done separately for manufacturing, farm, and nonfarm-nonmanufacturing. Sets of tables at the end of this appendix present annual figures for equipment, structures, rental residential capital, inventories, and land, as well as the total for all types of assets. The discussion in this appendix will be directed mainly at the private business sector, tables C–13 through C–19. However, much of the discussion applies equally to the private nonfarm business sector (C–20 through C–26) and the manufacturing sector (C–27 through C–33).

Referring to table C–13, one can examine the annual percent changes in the private business capital measure. With two minor exceptions, every component exhibits positive growth in every year. Steady growth is not surprising in light of the growth of the economy, but the uniformity of growth, even during business downturns, exemplifies the rather static nature of capital as measured. The main contributor to the measure is a stock estimate, which is determined by historical investments net of efficiency loss (which is assumed to occur at a small, predetermined rate). New gross investment (table C–17) is added to the stock each year, and accruing efficiency losses are removed. Gross investment is relatively volatile but has always been great enough to offset efficiency losses. Large positive and negative fluctuations in the growth of investment result in more modest changes in the rate at which capital inputs increase (C–13). Analogous observations apply to the private nonfarm business and manufacturing sectors.

Referring again to table C–13, a clear pattern emerges when comparing the growth rates of various asset types. Equipment consistently grows faster than structures which, in turn, generally grow faster than residential capital, inventories, or land. In other words, there has been a long-term shift in the composition of capital towards depreciable assets, particularly the shorter lived equipment. This shift in the overall capital measures is captured by the use of rental prices to weight capital assets during aggregation. The effect of the shift on the capital input measures can be judged by comparing the growth of capital input for all assets (table C–13) with that of an index of the direct aggregate of productive stocks (table C–14). Table C–16 shows the index of the ratio of capital input to productive stock, which is sometimes referred to as the capital "composition effect." Clearly, the shift toward shorter lived assets has caused a steady and significant increase in capital services per unit of stock. This is because equipment yields its services more quickly than structures and hence is assigned a larger weight. Also, the decline in this effect since 1973 reflects in part the lower revaluation of equipment. Presumably, investment

[26] John P. Doll and Richard Widdows, *"Imputing Returns to Production Assets in 10 U.S. Farm Production Regions"*, Economic Research Service Staff Report No. ACES820703 (U.S. Department of Agriculture, July 1982).

Table C–5. Manufacturing sector: Shares in total income used to aggregate labor and capital inputs, 1948–81

Year	Ratio adjusting proprietors' wages and rate of return to noncorporate capital (1)	Total adjusted labor share (2)	Breakdown of adjusted labor share: Employees (3)	Breakdown of adjusted labor share: Proprietors (4)	Breakdown of adjusted capital share: Corporate (5)	Breakdown of adjusted capital share: Noncorporate (6)
1948	0.9338	0.681	0.662	0.019	0.307	0.012
1949	.8215	.670	.652	.017	.317	.014
1950	.8745	.656	.640	.016	.329	.014
1951	.9372	.661	.645	.016	.326	.013
1952	.8341	.683	.668	.014	.304	.014
1953	.7492	.694	.681	.013	.293	.014
1954	.6353	.696	.685	.011	.290	.014
1955	.5482	.671	.662	.009	.315	.015
1956	.7744	.694	.681	.013	.295	.010
1957	.6118	.697	.686	.010	.291	.012
1958	.4618	.706	.698	.008	.280	.014
1959	.3043	.683	.678	.005	.302	.015
1960	.3087	.696	.691	.005	.290	.014
1961	.2207	.693	.689	.004	.292	.015
1962	.2285	.686	.683	.004	.301	.013
1963	.2591	.675	.671	.004	.313	.012
1964	.3340	.672	.668	.004	.317	.012
1965	.3078	.658	.654	.004	.331	.011
1966	.3956	.671	.666	.004	.320	.009
1967	.3595	.684	.680	.004	.307	.008
1968	.3596	.684	.680	.004	.308	.008
1969	.4244	.704	.699	.005	.290	.006
1970	.4384	.723	.717	.005	.272	.005
1971	.3991	.701	.697	.004	.294	.005
1972	.4232	.701	.696	.004	.294	.006
1973	.4679	.712	.706	.005	.284	.004
1974	.6396	.741	.734	.007	.256	.002
1975	.5130	.711	.705	.006	.287	.003
1976	.3756	.701	.697	.004	.294	.004
1977	.4206	.700	.695	.005	.297	.003
1978	.4756	.710	.704	.006	.288	.003
1979	.5160	.732	.726	.007	.266	.001
1980	.4744	.757	.750	.007	.243	.000
1981	.4423	.748	.742	.006	.250	.002

composition is skewed toward equipment sufficiently so that $1 of new equipment no longer yields much more current services than new structures.

A further point can be made about the composition effect (table C–16). Since each major asset category is aggregated from subcategories of asset types with different rental prices (i.e., with different depreciation rates and for different sectors), a composition effect exists within each major category. The equipment effect is positive every single year, indicating a pervasive trend toward the shorter lived types of equipment. In contrast, the structures effect is often negative, indicating a slow trend toward longer lived forms of structures. The inventory and land effects reflect mainly intersectoral shifts. The land effect is persistently positive due to the relative growth of nonfarm land compared to farm land. The size of these composition effects demonstrates the results of measuring capital services as a detailed array of assets rather than at a more aggregate level.

Table C–5 reports the shares of the major asset categories in total capital costs. Table C–18 shows the price index for new investment goods. Table C–19 shows the depreciation rates used in the rental price formulation. These are averages for more detailed rates used for individual assets.

Capital and labor income shares

In this section, the computation of the capital and labor shares of income is illustrated. As discussed earlier in this appendix, an estimation procedure is required to allocate proprietors' income between labor and capital, basically a two-step process. The first step is to approximate labor compensation using employee compensation per hour times proprietors' hours and to approximate capital compensation assuming the corporate and noncorporate rental price of capital to be equal. The second step is to adjust the capital and labor compensation figures so that they equal the reported figures for proprietors' income.

Tables C–5, C–6, and C–7 refer to the manufacturing, farm, and nonfarm-nonmanufacturing portions of the private business sector, respectively. In each table, column 1 illustrates the adjustment made; in manufacturing (C–5) and in nonmanufacturing (C–7), this column indicates the factor by which ''first'' estimates of proprietors' wages and the rate of return to noncorporate capital had to be multiplied to ''control'' their associated values to the NIPA proprietors' income figure. The most significant observation is that this adjustment is less than 1.00 and thus involves decreasing the ''first'' estimates in both sectors, more so in manufacturing. For the farm sector (table C–6), this adjustment is applied only to the proprietors' wage rate. It is assumed that farm noncorporate capital earns the same rate of return as corporate capital; any shortfall or excess in proprietors' income is attributed as a differential in the wage of proprietors compared to that of corporate employees. The farm adjustment is usually, but not always, less than 1.00. The most notable exceptions are in 1973 and 1974, when new farm subsidies were introduced.

Columns 3 through 6 in each table divide total income into shares arising from employees' labor, proprietors' labor, corporate capital, and noncorporate capital. These allow the reader to observe the relative importance of the noncorporate portion of each sector. Noncorporate enterprises are very important in the farm sector, but relatively small in manfuacturing.

Table C–6. Farm sector: Shares in total income used to aggregate labor and capital inputs, 1948–81

Year	Ratio adjusting proprietors' wages and rate of return to noncorporate capital (1)	Total adjusted labor share (2)	Breakdown of adjusted labor share: Employees (3)	Breakdown of adjusted labor share: Proprietors (4)	Breakdown of adjusted capital share: Corporate (5)	Breakdown of adjusted capital share: Noncorporate (6)
1948	0.8113	0.575	0.134	0.441	0.009	0.416
1949	.6410	.550	.157	.393	.010	.440
1950	.5247	.441	.148	.294	.012	.547
1951	.8418	.559	.133	.427	.010	.431
1952	1.0341	.717	.138	.579	.007	.276
1953	1.0148	.749	.141	.608	.007	.244
1954	.8625	.696	.140	.556	.009	.295
1955	1.0482	.719	.148	.571	.009	.272
1956	1.0622	.726	.149	.577	.009	.264
1957	1.0423	.728	.157	.571	.010	.262
1958	1.1399	.714	.149	.565	.011	.275
1959	.9735	.721	.169	.552	.012	.267
1960	1.1544	.694	.165	.529	.014	.293
1961	1.0336	.662	.170	.492	.016	.322
1962	.8919	.626	.174	.452	.019	.355
1963	.9097	.608	.179	.429	.021	.371
1964	.7304	.581	.197	.385	.023	.396
1965	.7372	.536	.176	.360	.026	.438
1966	.7176	.528	.169	.358	.027	.445
1967	.7894	.549	.176	.372	.027	.425
1968	.7108	.551	.181	.370	.031	.418
1969	.8283	.580	.173	.407	.033	.388
1970	.9040	.646	.179	.467	.030	.323
1971	.9965	.644	.169	.474	.033	.323
1972	1.1333	.603	.153	.450	.039	.358
1973	1.7150	.586	.113	.473	.043	.371
1974	1.7130	.643	.139	.503	.039	.319
1975	1.1699	.520	.147	.373	.054	.426
1976	.8853	.508	.179	.329	.057	.434
1977	.7957	.492	.191	.301	.061	.447
1978	.9261	.458	.167	.292	.067	.475
1979	1.1645	.503	.154	.349	.063	.434
1980	.5538	.401	.190	.211	.077	.522
1981	.7343	.425	.175	.250	.074	.501

Table C-7. Nonfarm-nonmanufacturing sector: Shares in total income used to aggregate labor and capital inputs, 1948-81

Year	Ratio adjusting proprietors' wages and rate of return to noncorporate capital (1)	Total adjusted labor share (2)	Breakdown of adjusted labor share		Breakdown of adjusted capital share	
			Employees (3)	Proprietors (4)	Corporate (5)	Noncorporate (6)
1948	0.6757	0.595	0.495	0.100	0.230	0.175
1949	.9515	.639	.494	.146	.226	.135
1950	.8382	.610	.488	.122	.237	.153
1951	.7442	.599	.497	.101	.233	.168
1952	.8747	.617	.502	.115	.230	.154
1953	.9272	.635	.510	.125	.227	.138
1954	.9144	.635	.508	.127	.231	.134
1955	.7483	.600	.500	.101	.243	.157
1956	.6493	.597	.508	.089	.240	.162
1957	.7129	.609	.509	.100	.240	.152
1958	.7232	.606	.503	.103	.243	.151
1959	.7061	.600	.503	.098	.248	.151
1960	.5950	.596	.512	.085	.249	.155
1961	.5620	.590	.510	.080	.252	.158
1962	.5569	.585	.509	.076	.257	.158
1963	.5166	.579	.511	.068	.258	.163
1964	.5824	.585	.509	.076	.260	.155
1965	.5985	.584	.509	.075	.264	.152
1966	.6439	.592	.515	.077	.265	.143
1967	.6848	.595	.518	.078	.265	.140
1968	.7060	.600	.522	.079	.265	.135
1969	.7512	.615	.532	.083	.262	.122
1970	.7551	.625	.543	.082	.258	.117
1971	.7715	.625	.540	.085	.262	.113
1972	.8716	.637	.544	.093	.262	.102
1973	.6931	.624	.550	.073	.258	.118
1974	.6910	.628	.555	.073	.257	.115
1975	.6564	.611	.543	.068	.274	.115
1976	.6904	.616	.546	.070	.271	.113
1977	.6548	.608	.541	.066	.276	.117
1978	.7435	.621	.545	.075	.275	.104
1979	.7282	.627	.552	.074	.268	.106
1980	.7196	.624	.551	.072	.272	.104
1981	.7117	.613	.544	.069	.279	.108

V. Sensitivity Analysis

The effects of two major issues concerning the measures of capital and multifactor productivity are explored in this section. These are: (1) The choice of assets to include as capital input, and (2) the mathematical form of the efficiency function.

Table C-8 shows growth rates during two major periods for multifactor productivity, capital input, and the distribution of capital input into the growth in the productive stock and the composition effect. The figures are for the private business sector; similar comparisons for private nonfarm business and manufacturing are shown in tables C-9 and C-10, respectively. The first column shows the actual figures published by BLS. The succeeding columns indicate what the results would be for a more restricted list of assets. The alternatives are computed using the same capital and labor income shares, and the same rental prices of capital for individual assets. The other four columns exclude selected asset types.

It is apparent that the final measure of multifactor productivity is only mildly reduced by excluding any of these assets, with the largest difference being 0.2 percent per year when land, inventories, and residential assets are all excluded. This is due partly to the fact that capital enters the multifactor measure only after being multiplied by capital's income share (roughly 0.35 during the two periods). The capital input measures are increased by up to 0.8 percent a year during 1973-81 by the exclusion of land, inventories, and the residential component. Thus, exclusion of these components from a capital measure would lead to attributing more growth of output per hour of all persons to capital per hour and less to multifactor productivity. The difference is greater in the recent period (1973-81) than in the earlier one (1948-73). Therefore, failure to include these assets would result in attributing less of the slowdown in output per hour to capital per hour and more to other sources. The differences, however, would be small; about 0.1 percentage point.

The effects on the unweighted productive stock of not

Table C–8. Private business sector: Growth rates including and excluding selected assets from published measures, 1948–81

(Percent per year, compounded)

Measure and period	All assets[1]	All assets excluding: Land	Inventories	Residential	Land, inventories, and residential
Multifactor productivity:[2]					
1948–81	1.5	1.5	1.5	1.4	1.3
1948–73	2.0	1.9	2.0	1.9	1.8
1973–81	0.1	0.1	0.1	0.1	−0.1
Quantity of capital services:[3]					
1948–81	3.5	3.6	3.4	3.7	4.0
1948–73	3.6	3.7	3.5	3.8	4.1
1973–81	3.2	3.4	3.3	3.5	4.0
Productive capital stock:[4]					
1948–81	2.6	3.2	2.6	2.8	3.8
1948–73	2.6	3.3	2.5	2.8	3.8
1973–81	2.7	3.2	2.8	2.9	3.7
Composition effects:[5]					
1948–81	0.8	0.4	0.9	0.9	0.3
1948–73	1.0	0.5	1.0	1.0	0.3
1973–81	0.5	0.2	0.5	0.6	0.2
Output per unit of capital input:					
1948–81	−0.1	−0.3	−0.1	−0.4	−0.7
1948–73	0.2	0.0	−0.2	−0.1	−0.3
1973–81	−1.0	−1.2	−1.0	−1.3	−1.7

[1] Equipment, structures, rental residential capital, inventories, and land.

[2]Output per unit of combined labor and capital inputs where the combined input is a weighted average of capital and labor (hours of all persons) inputs. The respective weights are capital's share (approximately 35 percent during the period) and labor's share (approximately 65 percent during the period).

[3]Aggregate productive capital stocks by asset type weighted by rental prices.

[4]Aggregate productive capital stocks by asset type, unweighted.

[5]Ratio of weighted to unweighted aggregate productive stocks.

including all the assets are even greater than on capital input; the difference was as much as 1.2 percentage points in 1948–73. This is because the composition effect is greater when more assets are included. It is apparent from the tables that much of the composition effect comes from inclusion of land, a factor which has a relatively low rental price and slow growth rate.

The second group of comparisons looks at the sensitivity of the multifactor productivity and capital input measures to the assumption about the form of the efficiency function. In order to do this, all steps in the measurement process were repeated using alternative assumptions about efficiency, including tracing through all of the implications for the rates of depreciation, rental prices, rates of return, and so on. Besides the hyperbolic form which was selected for the BLS measures, calculations were made using one-hoss-shay (gross stock) efficiency, straight-line efficiency (both with the same asset lives as the hyperbolic calculation), and with geometric decay using Hulten and Wykoff's "best geometric approximation" (BGA) rates of efficiency decline to construct the efficiency function.

Table C–11 presents annual rates of change and compound growth rates for selected periods for the resulting private business multifactor productivity measures. It is evident that the method selected has little effect on the final measure of multifactor productivity, for year-to-year changes or over a long time period. The largest variation in the measure for any one year appears to be 0.4 percent (1966), while the largest effect on the longer term growth rate is 0.1 percent.

Table C–12 presents the same information for private business capital input, which is more sensitive to the efficiency assumption than is multifactor productivity.

Table C–9. Private nonfarm business sector: Growth rates including and excluding selected assets from published measures, 1948–81

(Percent per year, compounded)

Measure and period	All assets[1]	All assets excluding: Land	Inventories	Residential	Land, inventories, and residential
Multifactor productivity:[2]					
1948–81	1.3	1.2	1.3	1.2	1.1
1948–73	1.7	1.6	1.7	1.6	1.5
1973–81	0.0	0.0	0.0	−0.1	−0.2
Quantity of capital services:[3]					
1948–81	3.6	3.7	3.5	3.8	4.0
1948–73	3.6	3.7	3.6	3.9	4.1
1973–81	3.3	3.4	3.4	3.6	4.0
Productive capital stock:[4]					
1948–81	3.2	3.4	3.1	3.5	3.8
1948–73	3.2	3.4	3.1	3.6	3.9
1973–81	3.1	3.2	3.1	3.3	3.7
Composition effects:[5]					
1948–81	0.3	0.3	0.4	0.3	0.2
1948–73	0.4	0.3	0.4	0.3	0.2
1973–81	0.2	0.2	0.2	0.2	0.2
Output per unit of capital input:					
1948–81	−0.1	−0.2	−0.1	−0.4	−0.6
1948–73	0.2	0.1	0.3	−0.1	−0.2
1973–81	−1.1	−1.2	−1.2	−1.4	−1.8

[1]Equipment, structures, rental residential capital, inventories, and land.

[2]Output per unit of combined labor and capital inputs where the combined input is weighted average of capital and labor (hours of all persons) inputs. The respective weights are capital's share (approximately 35 percent during the period) and labor's share (approximately 65 percent during the period.

[3]Aggregate productive capital stocks by asset type weighted by rental prices.

[4]Aggregate productive capital stocks by asset type, unweighted.

[5]Ratio of weighted to unweighted aggregate productive stocks.

Table C-10. Manufacturing sector: Growth rates including and excluding selected assets from published measures, 1948-81

(Percent per year, compounded)

Measure and period	All assets[1]	All assets excluding:		
		Land	Inventories	Land and inventories
Multifactor productivity:[2]				
1948-81	1.8	1.7	1.8	1.7
1948-73	2.2	2.2	2.2	2.2
1973-81	0.4	0.3	0.3	0.2
Quantity of capital services:[3]				
1948-81	3.6	3.7	3.5	3.7
1948-73	3.5	3.5	3.3	3.4
1973-81	4.0	4.1	4.3	4.5
Productive capital stock:[4]				
1948-81	3.3	3.4	3.2	3.4
1948-73	3.1	3.3	3.0	3.1
1973-81	3.7	3.8	3.9	4.1
Composition effect:[5]				
1948-81	0.3	0.3	0.4	0.3
1948-73	0.3	0.2	0.4	0.3
1973-81	0.3	0.3	0.4	0.4
Output per unit of capital input:				
1948-81	−0.2	−0.3	−0.2	−0.3
1948-73	0.6	0.5	0.7	0.6
1973-81	−2.6	−2.8	2.9	−3.1

[1]Equipment, structures, inventories, and land.

[2]Output per unit of combined labor and capital inputs where the combined input is a weighted average of capital and labor (hours of all persons) inputs. The respective weights are capital's share (approximately 35 percent during the period) and labor's share (approximately 65 percent during the period).

[3]Aggregate productive capital stocks by asset type weighted by rental prices.

[4]Aggregate productive capital stocks by asset type, unweighted.

[5]Ratio of weighted to unweighted aggregate productive stocks.

However, the practical difference between efficiency assumptions is again small. The largest annual variation is 1.2 percent (1966), and the largest for a time period is 0.5 percent. It is interesting that the widest differences are between gross and straight-line methods. A case in point is 1967, when these two differed by 0.9 percentage point, while the hyperbolic and geometric results differed by only 0.3 percentage point. The close conformity of the hyperbolic and the BGA series is due in large part to the fact that both were selected for their conformity to the age/price profiles measured by Hulten and Wykoff.

VI. Summary

The BLS measures of capital input have been constructed to represent the flow of services attributable to the stock of physical assets. Stocks are measured by a perpetual inventory calculation to estimate relative service flow, by detailed asset type, from assets of different vintages. The perpetual inventory method employs a hyperbolic efficiency function in which services decline relatively slowly during the early years of an asset's life and more quickly later. A slower hyperbolic form is used for structures than for equipment, because comparisons between the age/price profiles consistent with various hyperbolic forms and the Hulten-Wykoff research on used asset prices indicated that this distinction was appropriate. Rental prices are constructed by assuming that the value of a new asset equals the discounted stream of services it will provide. Rates of return in the rental price expression are derived from asset stocks and from the NIPA data on the components of income.

Labor and capital income shares used to aggregate the two inputs are based on employee compensation and corporate capital income figures from the NIPA and also on a procedure which allocates proprietors' income to labor and capital. In the private nonfarm sector, this allocation reduces both noncorporate labor's compensation per hour and capital's rate of return after having initially assumed that these variables are equal to their corporate sector counterparts. In the farm sector, where proprietorship is the dominant legal form of organization, corporate capital is assumed to earn the noncorporate rate of return, with the residual of proprietors' income being attributed to labor.

Extensive detail is presented in the following tables, C-13 through C-33. For each major asset and in each sector, there are measures of capital input, productive capital stock, the asset's share in capital income, and indexes showing the effects of changes in the composition of assets over time.

Sensitivity analysis indicates that capital measures are somewhat sensitive to the inclusion of land, inventories, and residential capital and to the pattern of efficiency assumed. However, multifactor productivity measures are much less sensitive because the capital measures are weighted by capital's share (approximately equal to 35 percent). These issues have only relatively small effects on the conclusions which can be drawn about multifactor productivity growth and the post-1973 slowdown.

Table C–11. Sensitivity of multifactor productivity measure to relative efficiency assumptions, private business sector, 1949–81

(Percent change)

Period	BLS (hyperbolic)	Hulten/Wykoff (best geometric approximation)	Gross (one hoss shay)	Straight line
1949	−1.1	−1.0	−1.0	−1.2
1950	7.2	7.4	7.2	7.1
1951	2.4	2.5	2.5	2.2
1952	1.8	2.0	1.8	1.8
1953	2.6	2.8	2.5	2.6
1954	−0.4	−0.3	−0.5	−0.4
1955	4.4	4.4	4.3	4.3
1956	0.3	0.4	0.4	0.2
1957	0.9	1.0	0.9	0.8
1958	0.7	0.8	0.5	0.7
1959	4.0	4.1	3.9	4.1
1960	0.6	0.5	0.6	0.6
1961	2.0	1.9	1.9	1.9
1962	3.6	3.6	3.6	3.6
1963	2.9	2.8	2.9	2.8
1964	3.6	3.6	3.7	3.5
1965	3.1	3.1	3.3	3.0
1966	1.9	2.0	2.2	1.8
1967	0.3	0.4	0.5	0.2
1968	2.4	2.5	2.5	2.3
1969	−0.5	−0.4	−0.4	−0.5
1970	−1.2	−1.0	−1.1	−1.2
1971	2.2	2.3	2.1	2.2
1972	3.3	3.4	3.2	3.3
1973	2.4	2.4	2.4	2.3
1974	−3.8	−3.7	−3.8	−3.8
1975	−0.2	−0.1	−0.3	−0.2
1976	3.8	3.8	3.6	3.9
1977	3.0	3.0	2.9	3.1
1978	1.0	1.0	1.0	1.0
1979	−1.1	−1.1	−1.2	−1.2
1980	−2.2	−2.2	−2.3	−2.2
1981	1.1	1.1	1.0	1.1
1948–65 ..	2.2	2.3	2.3	2.2
1965–73 ..	1.3	1.4	1.4	1.3
1948–73 ..	2.0	2.0	2.0	1.9
1973–81 ..	0.1	0.2	0.1	0.2
1948–81 ..	1.5	1.6	1.5	1.5

Table C–12. Sensitivity of capital services measure to relative efficiency assumptions, private business sector, 1949–81

(Percent change)

Period	BLS (hyperbolic)	Hulten/Wykoff (best geometric approximation)	Gross (one hoss shay)	Straight line
1949	4.0	3.5	3.5	4.2
1950	3.7	3.3	3.6	3.8
1951	4.4	4.0	4.0	4.7
1952	4.2	3.8	4.2	4.3
1953	3.1	2.5	3.3	3.0
1954	2.7	2.3	3.1	2.6
1955	3.1	3.0	3.3	3.2
1956	3.6	3.5	3.5	3.9
1957	3.1	2.9	3.2	3.3
1958	2.2	1.8	2.5	2.1
1959	2.0	1.8	2.4	1.8
1960	2.4	2.8	2.5	2.5
1961	2.2	2.3	2.3	2.2
1962	2.3	2.4	2.3	2.4
1963	2.9	3.1	2.8	3.2
1964	3.4	3.4	3.1	3.2
1965	4.3	4.2	3.8	4.7
1966	5.3	5.1	4.6	5.8
1967	5.3	5.0	4.8	5.7
1968	4.6	4.3	4.3	4.8
1969	4.7	4.4	4.4	4.8
1970	4.3	3.9	4.3	4.4
1971	3.5	3.1	3.7	3.4
1972	3.6	3.4	3.9	3.6
1973	4.6	4.4	4.6	4.6
1974	4.5	4.3	4.5	4.6
1975	2.7	2.4	3.0	2.5
1976	1.9	1.7	2.2	1.6
1977	2.6	2.5	2.8	2.5
1978	3.6	3.6	3.7	3.7
1979	3.7	3.5	3.8	3.8
1980	3.6	3.3	3.8	3.5
1981	2.9	2.6	3.1	2.7
1948–65 ..	3.1	3.0	3.1	3.3
1965–73 ..	4.5	4.2	4.3	4.6
1948–73 ..	3.6	3.4	3.5	3.7
1973–81 ..	3.2	3.0	3.4	3.1
1948–81 ..	3.5	3.3	3.5	3.6

Table C–13. Private business sector: Real capital input, 1948–81

Period	All assets	Equipment	Structures	Rental residential capital	Inventories	Land
	Index, 1977=100					
1948	37.1	24.9	43.8	61.9	34.6	57.0
1949	38.6	27.4	44.8	62.2	34.7	57.6
1950	40.0	29.5	45.6	62.8	35.3	58.1
1951	41.8	31.5	46.6	63.3	39.5	58.6
1952	43.5	33.4	47.7	63.5	42.7	59.1
1953	44.9	35.1	48.9	63.8	43.7	59.7
1954	46.1	36.5	50.2	64.1	43.3	60.5
1955	47.5	38.0	51.9	64.6	44.2	61.6
1956	49.2	39.8	53.8	65.1	46.8	62.8
1957	50.7	41.5	55.7	65.5	48.2	64.1
1958	51.9	42.5	57.5	66.0	47.8	65.3
1959	52.9	43.2	59.1	66.8	48.6	66.4
1960	54.1	44.1	60.8	67.9	50.9	67.2
1961	55.3	44.9	62.5	69.0	52.0	68.5
1962	56.6	45.8	64.2	70.5	53.4	70.0
1963	58.2	47.1	65.8	72.5	55.9	71.7
1964	60.2	49.1	67.5	74.8	58.2	73.5
1965	62.8	51.9	69.7	76.9	61.2	75.6
1966	66.1	55.8	72.4	78.6	65.8	77.8
1967	69.6	59.9	75.2	79.9	71.1	79.9
1968	72.7	63.5	78.0	81.4	75.5	82.0
1969	76.1	67.5	80.8	83.5	79.3	84.3
1970	79.4	71.4	83.5	85.7	82.4	86.6
1971	82.2	74.6	86.0	87.9	84.8	88.8
1972	85.2	77.9	88.5	91.3	87.6	91.1
1973	89.1	82.8	91.4	95.0	90.9	93.6
1974	93.1	88.4	94.4	97.1	94.9	95.7
1975	95.7	92.6	96.8	98.0	95.6	97.3
1976	97.5	95.9	98.4	98.8	96.4	98.7
1977	100.0	100.0	100.0	100.0	100.0	100.0
1978	103.6	105.7	102.1	101.5	105.3	101.7
1979	107.5	112.6	104.6	103.2	109.2	102.2
1980	111.3	119.1	107.4	104.8	109.9	105.8
1981	114.5	124.5	110.6	106.1	110.6	108.2
	Percent change from preceding year					
1949	4.0	9.7	2.4	0.6	0.3	1.0
1950	3.7	7.8	1.8	0.9	1.7	0.9
1951	4.4	6.9	2.1	0.7	12.0	0.8
1952	4.2	6.0	2.3	0.3	8.2	0.8
1953	3.1	5.0	2.5	0.4	2.3	1.1
1954	2.7	4.0	2.7	0.6	−0.7	1.3
1955	3.1	4.1	3.4	0.7	1.9	1.7
1956	3.6	4.6	3.7	0.7	5.8	2.0
1957	3.1	4.3	3.6	0.6	3.0	2.0
1958	2.2	2.6	3.3	0.8	−0.7	2.0
1959	2.0	1.6	2.8	1.3	1.7	1.7
1960	2.4	2.1	2.9	1.5	4.7	1.2
1961	2.2	1.9	2.8	1.7	2.1	1.9
1962	2.3	2.0	2.6	2.2	2.6	2.3
1963	2.9	2.9	2.5	2.9	4.8	2.3
1964	3.4	4.1	2.6	3.1	4.1	2.6
1965	4.3	5.8	3.3	2.8	5.2	2.8
1966	5.3	7.4	3.9	2.3	7.5	2.9
1967	5.3	7.3	3.8	1.7	8.1	2.7
1968	4.6	6.1	3.7	1.9	6.1	2.6
1969	4.7	6.3	3.7	2.6	5.0	2.8
1970	4.3	5.8	3.4	2.6	3.9	2.7
1971	3.5	4.4	3.0	2.6	3.0	2.6
1972	3.6	4.5	2.9	3.8	3.2	2.6
1973	4.6	6.3	3.2	4.1	3.9	2.7
1974	4.5	6.7	3.4	2.2	4.4	2.2
1975	2.7	4.8	2.5	0.9	0.7	1.8
1976	1.9	3.5	1.6	0.9	0.8	1.4
1977	2.6	4.3	1.6	1.2	3.7	1.3
1978	3.6	5.7	2.1	1.5	5.3	1.7
1979	3.7	6.5	2.5	1.7	3.7	0.5
1980	3.6	5.8	2.7	1.5	0.6	3.5
1981	2.9	4.5	3.0	1.3	0.6	2.3
	Compound annual rate of growth					
1948–81 ..	3.5	5.0	2.8	1.6	3.6	2.0
1948–73 ..	3.6	4.9	3.0	1.7	3.9	2.0
1973–81 ..	3.2	5.2	2.4	1.4	2.5	1.8

Table C–14. Private business sector: Productive capital stock, 1948–81

(Index, 1977=100)

Period	All assets	Equipment	Structures	Rental residential capital	Inventories	Land
1948	47.6	27.6	41.2	68.0	37.6	76.8
1949	48.7	30.1	42.1	68.1	37.8	77.3
1950	49.7	32.0	43.0	68.5	38.8	77.8
1951	51.1	34.1	44.0	68.8	42.6	78.1
1952	52.4	35.9	45.0	68.8	45.5	78.5
1953	53.4	37.6	46.1	68.9	46.4	79.0
1954	54.2	39.1	47.4	69.0	46.3	79.6
1955	55.3	40.5	48.9	69.2	47.2	80.2
1956	56.7	42.1	50.8	69.5	49.3	80.9
1957	57.9	43.6	52.7	69.7	50.5	81.2
1958	58.8	44.6	54.3	70.0	50.4	82.0
1959	59.7	45.2	55.9	70.6	51.3	82.6
1960	60.6	46.1	57.5	71.4	53.4	81.7
1961	61.6	46.9	59.4	72.3	54.5	82.0
1962	62.9	47.8	61.3	73.7	55.9	82.7
1963	64.5	49.1	63.2	75.7	58.4	83.5
1964	66.4	51.0	65.2	77.9	60.6	84.8
1965	68.7	53.8	67.7	79.9	63.4	85.9
1966	71.5	57.5	70.7	81.6	67.5	87.2
1967	74.4	61.4	73.7	82.8	72.2	88.4
1968	77.1	65.1	76.6	84.1	76.0	89.5
1969	79.9	69.1	79.7	86.1	79.4	90.9
1970	82.6	72.9	82.7	88.1	82.2	92.2
1971	85.0	75.9	85.4	90.0	84.4	93.6
1972	87.5	79.1	88.0	92.6	87.1	94.9
1973	90.7	83.8	91.0	95.6	90.8	96.5
1974	94.1	89.1	93.9	97.5	94.9	98.2
1975	96.3	93.1	96.3	98.3	96.6	99.3
1976	97.9	96.1	98.1	99.0	97.2	99.5
1977	100.0	100.0	100.0	100.0	100.0	100.0
1978	103.1	105.6	102.2	101.4	104.7	101.0
1979	105.9	112.3	104.9	103.0	108.4	99.3
1980	109.6	118.5	107.7	104.4	109.2	104.0
1981	112.5	123.8	110.9	105.6	110.0	105.7

Table C–15. Private business sector: Shares in current capital cost, 1948–81

Period	All assets	Equipment	Structures	Rental residential capital	Inventories	Land
1948	1.000	0.291	0.265	0.220	0.138	0.085
1949	1.000	.334	.340	.099	.136	.091
1950	1.000	.379	.350	.125	.030	.116
1951	1.000	.345	.219	.180	.197	.059
1952	1.000	.345	.296	.132	.156	.072
1953	1.000	.443	.301	.103	.088	.065
1954	1.000	.417	.347	.089	.061	.086
1955	1.000	.364	.333	.135	.070	.098
1956	1.000	.312	.232	.191	.174	.090
1957	1.000	.400	.271	.142	.108	.080
1958	1.000	.328	.356	.120	.076	.120
1959	1.000	.442	.294	.110	.082	.073
1960	1.000	.402	.318	.126	.085	.069
1961	1.000	.403	.311	.102	.072	.113
1962	1.000	.380	.313	.111	.095	.101
1963	1.000	.376	.296	.124	.107	.098
1964	1.000	.353	.306	.111	.119	.111
1965	1.000	.335	.306	.114	.125	.121
1966	1.000	.374	.282	.112	.129	.103
1967	1.000	.354	.295	.105	.136	.111
1968	1.000	.362	.309	.097	.123	.110
1969	1.000	.429	.258	.105	.128	.080
1970	1.000	.425	.264	.102	.123	.086
1971	1.000	.416	.274	.088	.137	.085
1972	1.000	.427	.306	.035	.120	.112
1973	1.000	.411	.295	.121	.066	.107
1974	1.000	.433	.238	.219	.047	.063
1975	1.000	.222	.268	.128	.159	.222
1976	1.000	.297	.352	.090	.105	.155
1977	1.000	.313	.306	.120	.129	.133
1978	1.000	.370	.255	.106	.144	.125
1979	1.000	.370	.269	.127	.093	.142
1980	1.000	.349	.275	.126	.098	.153
1981	1.000	.284	.301	.100	.147	.168

Table C-16. Private business sector: Ratio of capital services to productive stock, 1948–81

(Index, 1977=100)

Period	All assets	Equip-ment	Struc-tures	Rental residential capital	Inven-tories	Land
1948	77.9	90.4	106.3	91.0	91.8	74.2
1949	79.2	90.9	106.4	91.4	91.6	74.4
1950	80.5	92.2	106.2	91.7	90.8	74.7
1951	81.7	92.5	106.0	92.0	92.6	75.0
1952	83.0	93.0	106.0	92.2	93.9	75.2
1953	84.0	93.3	105.9	92.6	94.1	75.6
1954	84.9	93.4	105.9	93.0	93.7	76.1
1955	85.9	93.8	106.1	93.3	93.7	76.7
1956	86.8	94.5	106.0	93.7	94.8	77.7
1957	87.7	95.1	105.8	94.0	95.4	78.9
1958	88.2	95.4	105.9	94.3	94.8	79.6
1959	88.6	95.6	105.9	94.7	94.8	80.5
1960	89.3	95.6	105.7	95.1	95.4	82.3
1961	89.7	95.7	105.3	95.4	95.5	83.5
1962	89.9	95.8	104.8	95.6	95.5	84.7
1963	90.3	95.9	104.2	95.8	95.7	85.8
1964	90.7	96.2	103.6	96.0	96.0	86.7
1965	91.4	96.6	103.0	96.2	96.5	87.9
1966	92.4	97.0	102.4	96.4	97.4	89.2
1967	93.5	97.4	102.0	96.6	98.6	90.3
1968	94.4	97.6	101.8	96.8	99.3	91.6
1969	95.3	97.7	101.4	97.0	99.8	92.7
1970	96.1	98.0	101.0	97.3	100.2	93.9
1971	96.7	98.2	100.7	97.7	100.5	94.9
1972	97.4	98.5	100.5	98.6	100.5	96.0
1973	98.2	98.9	100.4	99.4	100.2	97.0
1974	99.0	99.1	100.5	99.6	100.0	97.4
1975	99.3	99.5	100.6	99.7	99.0	98.0
1976	99.6	99.8	100.3	99.8	99.2	99.1
1977	100.0	100.0	100.0	100.0	100.0	100.0
1978	100.5	100.1	99.9	100.1	100.6	100.6
1979	101.5	100.3	99.8	100.3	100.7	103.0
1980	101.6	100.6	99.7	100.4	100.6	101.7
1981	101.8	100.6	99.8	100.5	100.5	102.3

Table C-17. Private business sector: Gross real investment, 1948–81

(Index, 1977=100)

Period	All assets	Equipment	Structures	Rental residential capital
1948	40.9	37.2	51.4	37.8
1949	34.7	29.4	47.1	38.7
1950	37.8	32.3	48.9	51.0
1951	39.3	34.6	51.9	37.9
1952	38.1	33.0	51.7	36.3
1953	40.7	34.9	56.2	38.6
1954	40.1	33.1	57.7	40.9
1955	45.0	36.5	66.2	46.7
1956	46.7	37.5	71.2	43.6
1957	47.5	38.8	70.3	45.2
1958	42.0	32.5	64.4	50.3
1959	46.1	36.3	66.6	64.0
1960	48.4	37.8	72.0	63.2
1961	48.7	36.6	73.5	74.6
1962	53.2	40.4	76.8	91.2
1963	56.4	43.5	76.4	109.4
1964	61.8	49.6	82.0	107.4
1965	70.9	57.6	97.4	101.8
1966	76.8	66.0	102.1	86.0
1967	74.4	64.2	99.5	78.1
1968	78.6	67.6	101.9	98.7
1969	84.8	73.0	107.7	115.0
1970	81.4	70.6	104.3	100.8
1971	80.0	68.8	100.4	114.5
1972	88.9	77.6	104.3	144.5
1973	101.6	92.5	114.4	143.8
1974	97.2	93.7	109.1	84.9
1975	85.2	81.7	95.7	78.8
1976	89.0	87.3	94.7	83.3
1977	100.0	100.0	100.0	100.0
1978	113.9	116.0	110.1	108.5
1979	121.1	122.6	118.4	116.4
1980	119.1	119.0	122.6	105.6
1981	122.9	121.2	131.6	104.2

Table C-18. Private business sector: Price of new capital goods, 1948–81

(Index, 1977=100)

Period	All assets	Equip-ment	Struc-tures	Rental residential capital	Inven-tories	Land
1948	28.8	33.3	30.2	35.8	45.5	18.2
1949	29.4	35.0	30.2	36.8	42.3	19.3
1950	30.4	36.4	30.7	38.0	47.3	19.2
1951	33.3	39.6	34.7	39.5	48.6	21.8
1952	34.7	41.8	35.9	40.5	46.1	23.8
1953	35.2	41.5	36.8	41.4	46.0	24.4
1954	35.2	41.8	36.2	42.2	45.6	24.4
1955	35.8	42.7	36.1	42.9	45.3	25.2
1956	38.2	47.9	40.0	43.3	47.4	26.3
1957	39.6	49.1	41.9	43.8	48.9	27.7
1958	40.8	52.2	41.6	44.5	50.2	28.9
1959	41.1	51.0	41.6	44.5	49.2	30.5
1960	41.7	51.5	41.6	44.5	49.7	31.6
1961	41.6	51.5	41.4	44.4	49.6	31.6
1962	42.0	51.5	41.3	44.4	49.6	32.6
1963	42.5	51.5	41.8	44.0	49.5	33.6
1964	43.3	51.9	42.3	44.5	49.6	35.1
1965	44.5	53.2	43.1	45.3	50.9	36.4
1966	46.1	53.8	44.9	46.5	51.8	38.7
1967	47.9	55.8	46.7	48.5	52.4	40.8
1968	50.0	57.8	48.5	51.1	53.9	43.0
1969	53.1	59.8	52.6	54.6	56.5	45.8
1970	56.2	62.9	56.9	58.4	58.2	48.4
1971	59.6	65.4	61.4	63.4	60.3	51.4
1972	63.4	67.2	65.1	71.6	64.0	55.2
1973	68.5	68.8	69.8	76.3	73.1	61.1
1974	79.2	75.0	82.6	81.2	85.0	75.1
1975	87.2	87.2	91.5	87.4	90.2	81.3
1976	92.8	93.5	94.4	94.3	94.6	89.0
1977	100.0	100.0	100.0	100.0	100.0	100.0
1978	109.5	105.9	111.4	110.9	109.8	110.5
1979	122.5	114.5	125.9	122.5	124.5	125.9
1980	136.6	124.7	141.5	135.0	140.3	142.8
1981	147.4	134.7	153.4	148.4	146.8	155.3

Table C-19. Private business sector: Rate of depreciation, 1948–81

(Percent per year)

Period	All assets	Equipment	Structures	Rental residential capital
1948	3.229	11.930	5.772	2.218
1949	3.463	12.382	5.741	2.247
1950	3.529	12.535	5.700	2.264
1951	3.613	12.729	5.660	2.295
1952	3.730	12.955	5.638	2.323
1953	3.803	13.043	5.609	2.348
1954	3.897	13.222	5.587	2.373
1955	3.941	13.245	5.540	2.392
1956	3.954	13.366	5.498	2.416
1957	3.997	13.412	5.474	2.442
1958	4.093	13.651	5.480	2.463
1959	4.108	13.661	5.469	2.475
1960	4.115	13.716	5.445	2.494
1961	4.136	13.806	5.425	2.502
1962	4.140	13.779	5.399	2.497
1963	4.145	13.753	5.386	2.483
1964	4.167	13.666	5.358	2.476
1965	4.187	13.523	5.302	2.477
1966	4.236	13.376	5.257	2.495
1967	4.333	13.461	5.236	2.516
1968	4.394	13.465	5.215	2.524
1969	4.451	13.451	5.188	2.532
1970	4.537	13.593	5.181	2.558
1971	4.603	13.727	5.184	2.578
1972	4.640	13.726	5.175	2.589
1973	4.691	13.644	5.152	2.616
1974	4.809	13.742	5.150	2.681
1975	4.970	14.042	5.181	2.740
1976	5.041	14.118	5.215	2.784
1977	5.098	14.117	5.241	2.818
1978	5.152	14.075	5.254	2.849
1979	5.259	14.150	5.262	2.879
1980	5.410	14.339	5.271	2.917
1981	5.516	14.465	5.277	2.949

Table C–20. Private nonfarm business sector: Real capital input, 1948–81

Period	All assets	Equip-ment	Struc-tures	Rental residential capital	Inven-tories	Land
	Index, 1977=100					
1948	36.3	24.7	43.9	60.6	33.8	49.7
1949	37.7	26.9	44.9	61.0	33.9	50.4
1950	39.0	28.8	45.6	61.7	34.5	51.0
1951	40.6	30.6	46.6	62.3	39.0	51.7
1952	42.4	32.5	47.6	62.5	42.2	52.3
1953	43.7	34.2	48.8	62.9	43.1	53.1
1954	44.9	35.6	50.1	63.3	42.8	54.0
1955	46.4	37.1	51.8	63.8	43.6	55.0
1956	48.1	39.0	53.7	64.3	46.2	56.4
1957	49.7	40.7	55.7	64.7	47.6	57.7
1958	50.8	41.9	57.5	65.2	47.3	59.0
1959	51.9	42.6	59.1	66.1	48.0	60.2
1960	53.2	43.5	60.8	67.1	50.4	61.6
1961	54.4	44.4	62.5	68.3	51.4	63.1
1962	55.7	45.3	64.2	69.9	52.8	64.8
1963	57.4	46.7	65.8	71.9	55.3	66.6
1964	59.4	48.6	67.5	74.2	57.7	68.6
1965	62.0	51.5	69.7	76.3	60.7	70.9
1966	65.3	55.4	72.5	78.1	65.3	73.4
1967	68.9	59.5	75.2	79.5	70.7	75.8
1968	72.1	63.2	78.0	81.0	75.1	78.2
1969	75.6	67.2	80.9	83.2	78.9	80.8
1970	78.9	71.2	83.6	85.4	82.1	83.6
1971	81.8	74.4	86.1	87.6	84.5	86.1
1972	84.8	77.8	88.6	91.0	87.3	88.8
1973	88.8	82.8	91.5	94.9	90.6	91.8
1974	93.0	88.4	94.5	97.1	94.8	94.4
1975	95.6	92.6	96.9	97.9	95.5	96.5
1976	97.4	95.9	98.4	98.8	96.3	98.2
1977	100.0	100.0	100.0	100.0	100.0	100.0
1978	103.7	105.8	102.0	101.5	105.5	102.1
1979	107.9	112.8	104.5	103.3	109.3	104.6
1980	111.7	119.5	107.4	104.9	111.0	107.2
1981	115.0	125.1	110.5	106.3	110.7	110.1
	Percent change from preceding year					
1949	3.7	8.8	2.3	0.8	0.2	1.3
1950	3.5	7.1	1.7	1.2	1.7	1.2
1951	4.2	6.5	2.1	0.9	13.0	1.4
1952	4.3	6.1	2.2	0.4	8.3	1.3
1953	3.2	5.1	2.5	0.5	2.3	1.5
1954	2.8	4.2	2.7	0.7	−0.8	1.6
1955	3.3	4.3	3.4	0.8	1.9	2.0
1956	3.7	4.9	3.8	0.8	6.0	2.4
1957	3.3	4.6	3.6	0.7	3.1	2.5
1958	2.3	2.8	3.3	0.8	−0.8	2.2
1959	2.0	1.7	2.8	1.3	1.7	2.1
1960	2.6	2.2	2.9	1.6	4.8	2.2
1961	2.3	2.0	2.8	1.7	2.1	2.5
1962	2.4	2.1	2.6	2.3	2.6	2.7
1963	3.0	3.0	2.5	2.9	4.8	2.8
1964	3.5	4.2	2.6	3.2	4.2	3.0
1965	4.4	5.9	3.3	2.9	5.3	3.3
1966	5.4	7.5	3.9	2.3	7.6	3.5
1967	5.4	7.4	3.8	1.7	8.3	3.3
1968	4.7	6.2	3.7	1.9	6.2	3.2
1969	4.8	6.4	3.7	2.7	5.1	3.4
1970	4.5	5.9	3.4	2.7	3.9	3.4
1971	3.6	4.5	3.0	2.6	3.0	3.1
1972	3.7	4.6	2.9	3.9	3.3	3.1
1973	4.7	6.4	3.2	4.2	3.9	3.3
1974	4.7	6.8	3.4	2.3	4.6	2.9
1975	2.8	4.9	2.5	0.9	0.7	2.2
1976	1.9	3.5	1.6	0.9	0.8	1.8
1977	2.7	4.3	1.6	1.2	3.9	1.8
1978	3.7	5.8	2.0	1.5	5.5	2.1
1979	4.0	6.6	2.4	1.7	3.7	2.4
1980	3.5	5.9	2.7	1.6	0.7	2.6
1981	3.0	4.7	3.0	1.3	0.6	2.7
	Compound annual rate of growth					
1948–81 ..	3.6	5.0	2.8	1.7	3.7	2.4
1948–73 ..	3.6	5.0	3.0	1.8	4.0	2.5
1973–81 ..	3.3	5.3	2.4	1.4	2.5	2.3

Table C–21. Private nonfarm business sector: Productive capital stock, 1948–81

Index, 1977=100)

Period	All assets	Equip-ment	Struc-tures	Rental residential capital	Inven-tories	Land
1948	40.2	26.6	41.0	64.5	33.7	49.6
1949	41.2	28.9	41.9	64.8	33.8	50.1
1950	42.2	30.4	42.6	65.2	34.8	50.8
1951	43.7	32.3	43.6	65.7	38.6	51.5
1952	45.0	34.1	44.5	65.8	41.4	52.1
1953	46.0	35.7	45.6	66.0	42.2	52.9
1954	47.0	37.2	46.9	66.2	42.0	53.8
1955	48.2	38.7	48.4	66.5	42.8	54.9
1956	49.8	40.3	50.3	66.8	45.3	56.2
1957	51.3	42.1	52.3	67.2	46.6	57.6
1958	52.3	43.1	54.0	67.6	46.3	58.8
1959	53.4	43.8	55.5	68.3	47.1	60.1
1960	54.8	44.8	57.2	69.2	49.4	61.5
1961	56.1	45.7	59.1	70.2	50.5	63.0
1962	57.6	46.7	61.0	71.8	51.8	64.7
1963	59.5	48.1	62.9	73.9	54.3	66.6
1964	61.6	50.0	65.0	76.2	56.7	68.6
1965	64.2	52.8	67.6	78.4	59.8	70.8
1966	67.5	56.6	70.7	80.2	64.4	73.4
1967	70.7	60.6	73.7	81.5	69.6	75.8
1968	73.8	64.3	76.7	83.0	73.9	78.2
1969	77.1	68.5	79.8	85.1	77.7	80.8
1970	80.3	72.5	82.9	87.2	80.7	83.5
1971	83.0	75.6	85.7	89.2	83.0	86.0
1972	85.9	79.0	88.4	92.0	85.7	88.7
1973	89.5	83.8	91.3	95.2	89.4	91.6
1974	93.2	89.2	94.3	97.2	93.8	94.4
1975	95.7	93.2	96.6	98.1	95.6	96.4
1976	97.5	96.1	98.3	98.9	96.3	98.2
1977	100.0	100.0	100.0	100.0	100.0	100.0
1978	103.5	105.7	102.1	101.5	105.4	102.1
1979	107.3	112.6	104.6	103.2	109.3	104.5
1980	110.7	119.1	107.4	104.8	110.2	107.2
1981	114.1	124.9	110.6	106.1	111.1	110.0

Table C–22. Private nonfarm business sector: Shares in current capital cost, 1948–81

Period	All assets	Equip-ment	Struc-tures	Rental residential capital	Inven-tories	Land
1948	1.000	0.285	0.276	0.235	0.141	0.063
1949	1.000	.328	.361	.101	.142	.069
1950	1.000	.374	.375	.131	.021	.098
1951	1.000	.337	.226	.191	.206	.040
1952	1.000	.339	.306	.136	.161	.059
1953	1.000	.442	.309	.105	.089	.055
1954	1.000	.414	.360	.090	.061	.075
1955	1.000	.360	.342	.138	.071	.090
1956	1.000	.307	.236	.196	.178	.084
1957	1.000	.398	.275	.145	.109	.073
1958	1.000	.324	.365	.123	.076	.112
1959	1.000	.442	.300	.112	.082	.064
1960	1.000	.401	.326	.129	.085	.059
1961	1.000	.402	.318	.104	.072	.104
1962	1.000	.379	.321	.114	.096	.091
1963	1.000	.375	.302	.127	.108	.087
1964	1.000	.352	.312	.114	.121	.101
1965	1.000	.333	.313	.117	.127	.110
1966	1.000	.374	.288	.115	.132	.090
1967	1.000	.353	.301	.108	.139	.100
1968	1.000	.361	.315	.099	.125	.099
1969	1.000	.431	.262	.108	.130	.068
1970	1.000	.427	.268	.105	.124	.076
1971	1.000	.418	.278	.090	.139	.076
1972	1.000	.430	.312	.035	.122	.102
1973	1.000	.416	.303	.126	.064	.091
1974	1.000	.438	.242	.227	.045	.048
1975	1.000	.218	.274	.134	.163	.211
1976	1.000	.297	.361	.093	.107	.142
1977	1.000	.314	.313	.123	.131	.118
1978	1.000	.374	.261	.110	.147	.108
1979	1.000	.374	.275	.132	.094	.125
1980	1.000	.352	.282	.131	.099	.136
1981	1.000	.285	.039	.104	.151	.151

Table C–23. Private nonfarm business sector: Ratios of capital services to productive stock, 1948–81

(Index, 1977=100)

Period	All assets	Equipment	Structures	Rental residential capital	Inventories	Land
1948	90.3	92.7	107.1	93.9	100.4	100.3
1949	91.3	93.1	107.2	94.2	100.2	100.4
1950	92.3	94.5	107.1	94.6	99.1	100.4
1951	93.0	94.9	107.0	94.9	100.8	100.4
1952	94.2	95.4	106.9	95.0	102.0	100.4
1953	94.9	95.7	107.0	95.3	102.2	100.4
1954	95.7	95.7	106.9	95.6	102.0	100.3
1955	96.3	96.1	107.0	95.9	102.0	100.3
1956	96.7	96.6	106.8	96.1	102.0	100.3
1957	96.9	96.9	106.5	96.3	102.1	100.3
1958	97.2	97.1	106.5	96.5	102.1	100.3
1959	97.2	97.2	106.5	96.8	102.0	100.3
1960	97.1	97.1	106.3	97.1	101.9	100.1
1961	96.9	97.0	105.8	97.2	101.8	100.1
1962	96.7	97.0	105.2	97.4	101.8	100.1
1963	96.5	97.0	104.6	97.4	101.9	100.1
1964	96.4	97.2	103.9	97.3	101.6	100.1
1965	96.5	97.5	103.2	97.4	101.4	100.0
1966	96.9	97.8	102.5	97.4	101.4	100.0
1967	97.4	98.2	102.0	97.5	101.6	100.0
1968	97.7	98.2	101.7	97.6	101.7	100.0
1969	98.0	98.1	101.3	97.7	101.6	100.0
1970	98.3	98.2	100.8	97.9	101.6	100.1
1971	98.6	98.3	100.5	98.2	101.8	100.1
1972	98.8	98.5	100.3	99.0	101.8	100.2
1973	99.3	98.8	100.1	99.7	101.4	100.2
1974	99.8	99.0	100.2	99.8	101.1	100.1
1975	99.9	99.4	100.3	99.8	99.9	100.0
1976	99.9	99.8	100.1	99.9	99.9	100.0
1977	100.0	100.0	100.0	100.0	100.0	100.0
1978	100.2	100.1	100.0	100.1	100.0	100.0
1979	100.6	100.2	99.9	100.1	100.0	100.0
1980	100.9	100.3	99.9	100.1	99.9	100.1
1981	100.9	100.2	99.9	100.2	99.7	100.1

Table C–24. Private nonfarm business sector: Gross real investment, 1948–81

(Index, 1977=100)

Period	All assets	Equipment	Structures	Rental residential capital
1948	39.1	34.5	51.3	37.8
1949	32.4	26.1	46.8	38.7
1950	35.7	29.1	48.7	51.0
1951	37.7	32.1	52.2	37.9
1952	36.7	30.9	51.8	36.3
1953	39.8	33.1	57.2	38.6
1954	39.4	31.6	59.0	40.9
1955	44.5	35.0	68.5	46.7
1956	46.9	36.9	73.8	43.6
1957	47.8	39.3	73.2	45.2
1958	41.5	30.9	66.7	50.2
1959	45.5	34.9	68.0	64.0
1960	48.7	37.2	74.4	63.2
1961	48.8	35.7	75.9	74.6
1962	53.4	39.5	79.1	91.2
1963	56.5	42.4	78.8	109.4
1964	62.3	48.8	85.0	107.4
1965	71.4	56.6	101.6	101.8
1966	77.3	65.1	106.6	86.0
1967	74.5	63.1	103.1	78.0
1968	79.6	67.4	106.1	98.7
1969	86.2	73.2	112.2	115.0
1970	82.4	70.6	108.1	100.8
1971	80.8	68.5	103.8	114.5
1972	90.5	77.8	108.8	144.5
1973	102.6	92.3	118.3	143.8
1974	97.8	93.6	112.0	84.9
1975	84.5	80.5	96.5	78.8
1976	88.4	86.3	95.0	83.3
1977	100.0	100.0	100.0	100.0
1978	114.4	116.3	110.8	108.5
1979	122.2	123.5	120.4	116.4
1980	121.7	121.4	126.6	105.6
1981	126.2	124.4	136.6	104.2

Table C–25. Private nonfarm business sector: Price of new capital goods, 1948–81

(Index, 1977=100)

Period	All assets	Equipment	Structures	Rental residential capital	Inventories	Land
1948	33.8	33.5	29.9	35.3	43.0	31.8
1949	34.1	35.2	30.0	36.5	40.9	32.0
1950	35.5	36.7	30.6	37.7	45.2	32.6
1951	38.4	40.0	34.6	38.9	46.4	35.9
1952	39.6	42.2	35.9	40.0	45.6	37.1
1953	40.2	41.9	36.8	41.1	46.0	37.9
1954	40.2	42.1	36.2	41.9	46.3	37.6
1955	40.7	43.3	36.1	42.5	47.4	38.1
1956	43.9	48.6	40.1	43.0	49.3	41.0
1957	45.2	49.9	41.9	43.5	50.1	42.4
1958	45.9	53.0	41.7	44.3	50.3	42.3
1959	45.5	51.7	41.7	44.3	49.8	42.5
1960	45.8	52.2	41.8	44.3	49.8	43.3
1961	45.5	52.1	41.5	44.3	49.7	42.4
1962	45.4	52.1	41.4	44.3	49.6	42.3
1963	45.6	52.0	41.8	44.0	49.7	42.5
1964	46.0	52.4	42.3	44.4	50.0	42.8
1965	46.9	53.8	43.1	45.2	50.7	43.4
1966	48.2	54.3	44.8	46.4	51.7	45.1
1967	50.0	56.3	46.6	48.4	52.5	46.8
1968	51.9	58.3	48.3	51.0	53.9	48.6
1969	55.2	60.2	52.4	54.5	56.1	52.6
1970	58.8	63.3	56.8	58.4	58.4	56.7
1971	62.6	66.2	61.2	63.5	60.1	61.4
1972	66.1	67.6	64.9	71.8	62.3	65.2
1973	70.5	69.2	69.6	76.5	68.7	70.7
1974	81.1	75.2	82.3	81.3	83.1	85.5
1975	89.1	87.4	91.3	87.5	88.9	89.0
1976	93.9	93.7	94.4	94.4	94.0	93.1
1977	100.0	100.0	100.0	100.0	100.0	100.0
1978	109.4	105.7	111.5	110.8	108.1	111.9
1979	122.0	114.1	125.9	122.4	123.8	126.2
1980	135.4	124.0	141.4	134.9	139.7	141.0
1981	146.4	133.8	153.6	148.4	148.4	153.0

Table C–26. Private nonfarm business sector: Rate of depreciation, 1948–81

(Percent per year)

Period	All assets	Equipment	Structures	Rental residential capital
1948	4.183	11.788	5.851	2.206
1949	4.384	12.258	5.831	2.234
1950	4.453	12.381	5.800	2.251
1951	4.498	12.530	5.766	2.282
1952	4.573	12.732	5.752	2.310
1953	4.639	12.805	5.726	2.335
1954	4.732	12.974	5.705	2.359
1955	4.764	12.999	5.655	2.377
1956	4.798	13.107	5.609	2.401
1957	4.845	13.166	5.582	2.427
1958	4.939	13.451	5.587	2.448
1959	4.930	13.484	5.578	2.459
1960	4.919	13.536	5.553	2.478
1961	4.932	13.653	5.531	2.485
1962	4.909	13.638	5.504	2.479
1963	4.889	13.631	5.489	2.463
1964	4.874	13.548	5.459	2.456
1965	4.866	13.418	5.397	2.456
1966	4.878	13.272	5.347	2.475
1967	4.945	13.366	5.323	2.496
1968	4.977	13.346	5.299	2.504
1969	5.018	13.337	5.269	2.512
1970	5.101	13.493	5.261	2.538
1971	5.165	13.643	5.264	2.559
1972	5.184	13.647	5.252	2.571
1973	5.212	13.584	5.228	2.599
1974	5.310	13.693	5.228	2.665
1975	5.459	14.017	5.263	2.726
1976	5.527	14.103	5.304	2.770
1977	5.571	14.096	5.336	2.804
1978	5.628	14.057	5.355	2.837
1979	5.744	14.133	5.365	2.867
1980	5.896	14.316	5.372	2.905
1981	6.006	14.441	5.376	2.937

Table C-27. Manufacturing sector:
Real capital input, 1948–81

Period	All assets	Equipment	Structures	Inventories	Land
	Index, 1977=100				
1948	37.9	27.0	62.1	36.6	60.8
1949	39.5	29.5	63.9	36.1	62.2
1950	40.7	31.3	64.9	36.3	63.0
1951	43.2	33.4	65.7	41.5	63.9
1952	46.4	35.7	66.6	46.6	65.0
1953	48.2	37.7	67.8	48.3	65.9
1954	49.5	39.6	68.9	47.6	66.8
1955	51.0	41.4	70.7	47.5	68.2
1956	53.2	43.4	72.0	50.7	69.9
1957	55.2	45.8	73.0	52.3	71.5
1958	56.2	47.0	74.7	51.2	73.0
1959	56.6	47.3	75.6	51.3	74.0
1960	57.5	47.8	76.4	53.7	74.8
1961	58.3	48.3	77.6	54.7	75.8
1962	59.2	49.0	78.6	56.2	76.9
1963	60.7	50.0	79.7	58.9	78.0
1964	62.4	51.8	80.6	61.0	79.2
1965	65.1	54.9	82.1	63.9	80.7
1966	69.2	59.3	84.7	68.7	83.1
1967	74.2	64.4	87.9	75.3	85.9
1968	78.2	68.3	90.7	80.7	88.5
1969	81.3	71.3	93.2	84.4	90.7
1970	83.9	73.9	95.2	87.1	92.8
1971	85.2	75.5	96.4	87.6	94.3
1972	86.4	77.3	97.0	87.5	95.3
1973	88.6	80.4	97.6	89.6	96.2
1974	92.2	84.9	98.5	94.3	97.4
1975	95.5	90.0	99.2	97.6	98.4
1976	97.4	94.6	99.5	98.6	99.2
1977	100.0	100.0	100.0	100.0	100.0
1978	103.8	106.0	100.7	103.4	101.0
1979	108.8	113.4	102.1	107.5	102.5
1980	115.1	123.6	103.8	111.2	104.2
1981	121.1	135.3	105.5	112.9	106.0
	Percent change from preceding year				
1949	4.0	9.3	3.0	−1.4	2.4
1950	3.2	6.0	14.6	0.5	1.3
1952	7.5	7.0	1.5	12.3	1.7
1953	3.7	5.6	1.7	3.6	1.5
1954	2.7	5.1	1.6	−1.5	1.4
1955	3.1	4.5	2.7	−0.2	2.0
1956	4.3	4.9	1.9	6.6	2.5
1957	3.8	5.4	1.3	3.3	2.4
1958	1.7	2.7	2.3	−2.2	2.1
1959	0.8	0.5	1.3	0.4	1.3
1960	1.6	1.1	1.1	4.4	1.1
1961	1.4	1.1	1.5	1.9	1.4
1962	1.6	1.3	1.4	2.7	1.4
1963	2.4	2.1	1.3	4.9	1.4
1964	2.9	3.6	1.2	3.6	1.5
1965	4.2	5.9	1.9	4.7	2.0
1966	6.3	8.2	3.2	7.5	2.9
1967	7.2	8.5	3.8	9.6	3.4
1968	5.4	6.1	3.2	7.2	3.0
1969	3.9	4.3	2.7	4.6	2.6
1970	3.2	3.6	2.2	3.1	2.3
1971	1.6	2.2	1.2	0.6	1.6
1972	1.4	2.4	0.7	−0.1	1.1
1973	2.6	3.9	0.6	2.4	1.0
1974	4.1	5.6	0.9	5.2	1.2
1975	3.5	6.0	0.7	3.5	1.1
1976	2.0	5.1	0.3	1.0	0.8
1977	2.7	5.7	0.5	1.5	0.8
1978	3.8	6.0	0.7	3.4	1.0
1979	4.8	7.0	1.3	4.0	1.5
1980	5.8	9.0	1.7	3.4	1.7
1981	5.2	9.4	1.7	1.6	1.7
	Compound annual rate of growth				
1948–81 ...	3.6	5.0	1.6	3.5	1.7
1948–73 ...	3.5	4.5	1.8	3.5	1.9
1973–81 ...	4.0	6.7	1.0	2.9	1.2

Table C-28. Manufacturing sector:
Productive capital stock, 1948–81

(Index, 1977=100)

Period	All assets	Equipment	Structures	Inventories	Land
1948 ...	41.0	27.9	60.0	35.9	60.8
1949 ...	42.4	30.3	61.8	35.4	62.2
1950 ...	43.3	31.9	62.7	35.6	63.0
1951 ...	45.9	34.0	63.7	40.8	63.9
1952 ...	48.5	36.3	65.0	45.8	65.0
1953 ...	50.2	38.4	66.1	47.4	65.9
1954 ...	51.1	40.4	67.1	46.7	66.8
1955 ...	52.3	42.2	68.7	46.6	68.2
1966 ...	54.6	44.2	70.7	49.7	69.9
1957 ...	56.6	46.5	72.6	51.4	71.5
1958 ...	57.3	47.8	74.3	50.2	73.0
1959 ...	57.8	48.1	75.2	50.4	74.0
1960 ...	58.8	48.5	76.0	52.7	74.8
1961 ...	59.7	49.0	77.0	53.8	75.8
1962 ...	60.6	49.5	78.0	55.2	76.9
1963 ...	62.1	50.4	79.1	57.9	78.0
1964 ...	63.7	52.1	80.2	60.0	79.2
1965 ...	66.1	55.0	81.8	62.8	80.7
1966 ...	69.9	59.3	84.5	67.5	83.1
1967 ...	74.6	64.1	87.7	74.0	85.9
1968 ...	78.6	68.1	90.5	79.4	88.5
1969 ...	81.7	71.3	93.0	83.1	90.7
1970 ...	84.2	74.2	95.1	85.7	92.8
1971 ...	85.6	76.2	96.3	86.3	94.3
1972 ...	86.6	78.3	97.0	86.3	95.3
1973 ...	88.7	81.4	97.6	88.4	96.2
1974 ...	92.2	86.0	98.5	93.5	97.4
1975 ...	95.5	90.9	99.2	97.7	98.4
1976 ...	97.5	95.1	99.5	98.6	99.2
1977 ...	100.0	100.0	100.0	100.0	100.0
1978 ...	103.4	105.8	100.7	103.4	101.0
1979 ...	107.8	113.0	102.1	107.5	102.5
1980 ...	113.0	122.4	103.8	110.9	104.2
1981 ...	118.1	132.7	105.5	112.6	106.0

Table C-29. Manufacturing sector:
Shares in current capital cost, 1948–81

(Index, 1977=100)

Period	All assets	Equipment	Structures	Inventories	Land
1948 ...	1.000	0.356	0.350	0.248	0.045
1949 ...	1.000	.340	.371	.248	.041
1950 ...	1.000	.444	.427	.053	.076
1951 ...	1.000	.388	.179	.433	.000
1952 ...	1.000	.397	.300	.272	.030
1953 ...	1.000	.436	.356	.158	.050
1954 ...	1.000	.433	.388	.118	.060
1955 ...	1.000	.369	.452	.082	.097
1956 ...	1.000	.449	.156	.401	−.006
1957 ...	1.000	.446	.298	.220	.036
1958 ...	1.000	.431	.394	.117	.057
1959 ...	1.000	.448	.337	.168	.048
1960 ...	1.000	.466	.340	.146	.047
1961 ...	1.000	.488	.321	.151	.040
1962 ...	1.000	.450	.311	.195	.044
1963 ...	1.000	.457	.269	.238	.036
1964 ...	1.000	.429	.279	.248	.044
1965 ...	1.000	.400	.292	.254	.055
1966 ...	1.000	.425	.272	.254	.049
1967 ...	1.000	.426	.268	.262	.045
1968 ...	1.000	.443	.277	.234	.046
1969 ...	1.000	.526	.215	.236	.022
1970 ...	1.000	.543	.224	.213	.020
1971 ...	1.000	.508	.219	.248	.024
1972 ...	1.000	.480	.266	.212	.042
1973 ...	1.000	.522	.264	.169	.045
1974 ...	1.000	.635	.273	.046	.046
1975 ...	1.000	.273	.345	.306	.076
1976 ...	1.000	.349	.365	.198	.088
1977 ...	1.000	.406	.272	.260	.063
1978 ...	1.000	.476	.199	.286	.040
1979 ...	1.000	.514	.215	.225	.045
1980 ...	1.000	.541	.237	.174	.048
1981 ...	1.000	.391	.294	.245	.070

Table C–30. Manufacturing sector: Ratio of capital services to productive stock, 1948–81

(Index, 1977=100)

Period	All assets	Equipment	Structures	Inventories	Land
1948 ...	92.7	96.9	103.4	101.9	100.0
1949 ...	93.1	97.4	103.4	101.9	100.0
1950 ...	93.9	98.1	103.4	101.9	100.0
1951 ...	94.2	98.3	103.1	101.9	100.0
1952 ...	95.7	98.4	102.6	101.9	100.0
1953 ...	96.0	98.2	102.6	101.9	100.0
1954 ...	96.8	98.0	102.6	101.9	100.0
1955 ...	97.5	98.1	103.0	101.9	100.0
1956 ...	97.4	98.3	101.9	101.9	100.0
1957 ...	97.6	98.3	100.5	101.9	100.0
1958 ...	98.0	98.4	100.5	101.9	100.0
1959 ...	98.0	98.3	100.5	101.9	100.0
1960 ...	97.8	98.5	100.6	101.8	100.0
1961 ...	97.8	98.7	100.7	101.7	100.0
1962 ...	97.7	98.9	100.8	101.7	100.0
1963 ...	97.8	99.1	100.7	101.7	100.0
1964 ...	98.0	99.4	100.6	101.7	100.0
1965 ...	98.4	99.7	100.4	101.7	100.0
1966 ...	98.9	100.1	100.3	101.7	100.0
1967 ...	99.4	100.4	100.3	101.7	100.0
1968 ...	99.5	100.4	100.3	101.6	100.0
1969 ...	99.5	100.0	100.2	101.6	100.0
1970 ...	99.6	99.6	100.2	101.5	100.0
1971 ...	99.6	99.1	100.0	101.5	100.0
1972 ...	99.7	98.8	100.0	101.5	100.0
1973 ...	100.0	98.7	100.0	101.4	100.0
1974 ...	100.1	98.8	100.0	100.8	100.0
1975 ...	100.0	99.1	100.0	99.8	100.0
1976 ...	99.9	99.6	100.0	100.0	100.0
1977 ...	100.0	100.0	100.0	100.0	100.0
1978 ...	100.3	100.2	100.0	100.0	100.0
1979 ...	100.9	100.4	100.0	100.0	100.0
1980 ...	101.8	101.0	100.0	100.2	100.0
1981 ...	102.5	102.0	100.0	100.3	100.0

Table C–31. Manufacturing sector: Gross real investment, 1948–81

(Index, 1977=100)

Period	All assets	Equipment	Structures
1948	48.1	36.1	102.6
1949	36.3	27.4	76.8
1950	35.2	28.3	66.6
1951	43.7	35.3	82.0
1952	42.8	35.1	77.8
1953	43.3	35.7	77.8
1954	44.2	37.1	76.6
1955	47.0	35.2	100.9
1956	52.5	42.6	97.5
1957	53.2	43.1	99.6
1958	42.1	31.5	90.2
1959	39.5	32.5	71.7
1960	44.1	35.5	83.5
1961	43.6	34.3	86.1
1962	46.3	37.5	86.5
1963	49.6	41.0	89.0
1964	56.4	48.9	90.8
1965	69.4	59.8	113.4
1966	81.7	70.0	135.1
1967	83.7	71.3	140.1
1968	75.1	64.1	125.1
1969	77.8	66.8	127.8
1970	73.3	64.0	115.6
1971	65.5	58.3	98.4
1972	73.2	68.7	93.6
1973	79.2	75.3	96.9
1974	94.6	90.9	111.4
1975	86.0	84.6	92.6
1976	89.5	87.6	98.5
1977	100.0	100.0	100.0
1978	106.5	105.2	112.0
1979	126.1	125.6	128.2
1980	141.0	143.7	128.8
1981	147.2	149.8	134.9

Table C–32. Manufacturing sector: Price of new capital goods, 1948–81

(Index, 1977=100)

Period	All assets	Equipment	Structures	Inventories	Land
1948 ...	32.8	30.1	29.1	41.6	29.2
1949 ...	32.2	31.7	28.8	39.0	28.8
1950 ...	34.2	32.9	29.4	44.4	29.4
1951 ...	38.6	36.5	35.7	45.4	35.7
1952 ...	39.4	37.7	37.0	44.5	37.0
1953 ...	39.8	38.0	37.1	45.2	37.1
1954 ...	39.5	38.4	36.0	45.6	36.0
1955 ...	39.0	39.9	32.8	47.4	32.9
1956 ...	43.8	44.5	39.6	49.4	39.7
1957 ...	45.3	46.4	41.3	50.1	41.4
1958 ...	45.3	48.3	40.2	50.2	40.2
1959 ...	44.6	48.5	39.1	49.1	39.1
1960 ...	44.8	49.4	38.7	49.4	38.7
1961 ...	44.7	49.7	38.3	49.2	38.4
1962 ...	44.9	50.1	38.5	49.0	38.6
1963 ...	45.6	50.4	39.9	48.9	40.0
1964 ...	46.6	51.1	41.5	49.2	41.5
1965 ...	47.7	52.4	42.7	49.7	42.7
1966 ...	49.4	53.9	44.8	50.8	44.9
1967 ...	51.2	55.9	47.0	51.5	47.0
1968 ...	52.9	57.7	48.9	52.9	49.0
1969 ...	56.0	59.6	53.7	55.1	53.7
1970 ...	59.6	62.6	58.8	57.7	58.8
1971 ...	62.7	65.1	64.1	59.3	64.1
1972 ...	65.0	66.4	67.5	61.0	67.5
1973 ...	69.2	68.2	73.3	66.1	73.3
1974 ...	80.7	74.3	86.6	81.3	86.6
1975 ...	90.3	87.6	94.6	89.0	94.6
1976 ...	93.9	93.6	94.3	93.8	94.3
1977 ...	100.0	100.0	100.0	100.0	100.0
1978 ...	107.7	105.4	111.0	107.2	111.0
1979 ...	120.3	114.4	126.8	121.4	126.8
1980 ...	133.6	123.7	142.5	137.8	142.5
1981 ...	142.5	132.8	150.6	148.3	150.6

Table C–33. Manufacturing sector: Rate of depreciation, 1948–81

(Percent per year)

Period	All assets	Equipment	Structures
1949	4.961	11.423	5.628
1949	5.243	11.916	5.629
1950	5.374	12.149	5.639
1951	5.268	12.149	5.608
1952	5.250	12.295	5.611
1953	5.328	12.411	5.623
1954	5.469	12.494	5.639
1955	5.570	12.651	5.593
1956	5.535	12.610	5.598
1957	5.596	12.666	5.599
1958	5.788	13.041	5.634
1959	5.830	13.201	5.687
1960	5.794	13.299	5.711
1961	5.822	13.459	5.748
1962	5.810	13.505	5.788
1963	5.778	13.527	5.823
1964	5.765	13.411	5.856
1965	5.747	13.188	5.842
1966	5.723	12.975	5.802
1967	5.736	12.978	5.777
1968	5.800	13.160	5.796
1969	5.794	13.099	5.810
1970	5.841	13.140	5.854
1971	5.926	13.242	5.925
1972	5.961	13.141	5.988
1973	5.995	13.072	6.031
1974	5.959	12.869	6.055
1975	6.052	12.952	6.118
1976	6.166	12.992	6.165
1977	6.255	12.956	6.199
1978	6.364	13.047	6.208
1979	6.419	12.968	6.198
1980	6.566	12.976	6.201
1981	6.821	13.174	6.178

Appendix D. Hours of All Persons: Methods and Sources

The traditional BLS measures of output per hour of all persons and the new multifactor productivity measures of output per unit of combined labor and capital input use the same measures of labor input, except that the new productivity series excludes hours in government enterprises. Hours of labor represent about two-thirds of the combined labor and capital inputs in the new multifactor measures, and are the only input counted in the traditional productivity series. Using information gathered in monthly surveys, the Bureau of Labor Statistics aggregates measures of employment and average weekly hours at the 2-digit SIC level to major sector divisions for use in these two productivity series. The sources of data on employment and average weekly hours by sector and occupation used in the BLS productivity measures are summarized in table D–1.

Two sources of monthly information are used: The Current Employment Statistics program survey and the Current Population Survey. The Current Employment Statistics survey collects data for the employees of all nonagricultural establishments; hence it is often called the "establishment survey." The Current Population Survey obtains its information through household interviews and is called the "household survey."

Information collected in the establishment survey is regularly published in the B and C tables of *Employ-*

Table D–1. Sources of employment and hours data used in labor input measures for BLS productivity series, private business sector

Sector and occupation	Percent of private business hours (1982)	Employment		Average weekly hours		
				Directly collected		
		Establishment survey	Household survey	Establishment survey	Household survey	Not directly collected
Total	100					
Nonmanufacturing	69					
Employees:						
All employees	58	X				
Production workers	NA	X		X		
Nonproduction workers	NA					Assumed to be equal to average weekly hours for production workers
Self-employed:						
Proprietors and partners	11		X		X	
Unpaid family workers	1		X		X	
Manufacturing	27					
Employees:						
All employees	26	X				
Production workers	18	X		X		
Nonproduction workers	9					Estimates based on data from the BLS survey of employer expenditures for employee compensation, and production-worker average weekly hours.
Self-employed:						
Proprietors and partners	1		X		X	
Agriculture	4					
Farmers and farm managers	3		X		X	
Farm laborers and supervisors:						
Paid workers	2		X		X	
Unpaid family workers	([1])		X		X	

NA = not available.
[1]Less than 0.5 percent.
NOTE: Detail may not add to totals due to rounding.

ment and Earnings. Measures of employment and average weekly hours are collected for persons on the payrolls of approximately 180,000 establishments during the pay period which includes the 12th of the month. Since the hours are payroll hours, the measure includes paid leave time in addition to time spent at the work site. Persons who appear on the records of more than one establishment during the survey week are counted more than once, whether this results from multiple jobholding or job changes.

Since several categories of workers are outside the scope of the establishment survey, additional information is obtained from the household survey. These include self-employed individuals, farmers and farm workers, employees of private households, and unpaid family workers. Measures based on this survey are published in the A tables of *Employment and Earnings*. Monthly interviews are conducted in about 60,000 households to gather information on the labor force status and hours at work for the noninstitutional civilian population during the week including the 12th of the month. In this survey, multiple jobholders are counted only once, and all of their hours are assigned to the industry at which they worked most during the survey period. Only hours at work are counted; if a paid holiday occurs during the survey week, only 32 hours are reported even if 40 hours' pay is received.

For practical purposes, the hours data used in the BLS productivity measures are *hours paid* rather than *hours at work*. This is so because about 85 percent of total private business hours are taken from the establishment survey, which collects information on *hours paid*; only 15 percent comes from the household survey, which collects data on *hours at work* (table D–1).

In general, hours of all persons are computed by multiplying employment by average weekly hours at the 2-digit SIC level each month. These weekly values are converted to annual rates by multiplying them by 52. Seasonal factors are computed using a time span and method which correspond to the procedure for seasonally adjusting output used by the Bureau of Economic Analysis of the U.S. Department of Commerce. This avoids influencing productivity measures through the use of different seasonal adjustments to the numerator and denominator of the productivity ratios.

The seasonally adjusted results are summed to totals for private business, private nonfarm business, and manufacturing; quarterly averages are computed from three monthly levels. Annual averages are computed based on 12 months of data. Year-to-year changes are computed by comparing annual averages, rather than December to December movements.

Nonmanufacturing

Employees of establishments not engaged in manufacturing or agriculture account for about 58 percent of total hours in the private business sector. Data are collected for production workers in mining, construction workers in construction, and for nonsupervisory workers in transportation and public utilities, wholesale and retail trade, finance, insurance, and real estate, and business and personal services. Since employment is collected for all employees and for nonsupervisory workers, supervisors' employment can be computed by subtraction. Average weekly hours are collected for nonsupervisory workers only. For the purposes of productivity measurement, the average weekly hours of supervisory workers are assumed to be equal to those of nonsupervisory employees in the industry.

Self-employed and unpaid family workers in nonmanufacturing occupations contribute an additional 11 percent of private business hours. Information on the employment and average weekly hours for these workers is collected directly in the household survey.

Manufacturing

The hours of all persons engaged in the manufacturing sector account for about 27 percent of private business hours. Employment data are collected for production and related workers, and for all employees. Average weekly hours are collected only for production workers; average weekly hours of nonproduction workers are estimated based on information compiled in the BLS survey of employer expenditures for employee compensation and from production-worker average weekly hours.

The self-employed in manufacturing make up a very small proportion of the sector. Information on their employment and average weekly hours is obtained directly from the household survey.

Farm

Information on labor inputs in the farm sector comes from the household survey. Data are collected for farmers and farm managers, unpaid family workers, and paid farm workers. The number of farm proprietors is assumed to be equal to the number of farmers and farm managers reported in the labor force data; average weekly hours for self-employed persons in the labor force "agriculture" sector, which includes agriculture services as well as farm, are used to compute hours for farm proprietors. The number of 14- and 15-year-old unpaid family workers on farms is assumed equal to the number of unpaid family workers in this age group in "agriculture"; average weekly hours at work for agricultural unpaid family workers age 16 and over are used to compute hours of all unpaid family workers.

Employees on farms are represented in the household data as "paid workers." Employment levels of workers over 16 are available directly; those of 14- and 15-year-olds are estimated by subtracting 14- and 15-year-old unpaid family workers on farms (estimated as described above) from all farm workers in this age group; average weekly hours for wage and salary workers at work in agriculture age 16 and over are used to compute hours for all employees on farms.

Government enterprises

Hours for government enterprises are measured by first establishing quarterly employee totals for Federal, State, and local government enterprises and then applying these employment levels to average weekly hours of all government workers, available from the household survey. The quarterly employee levels are obtained by extrapolating annual BEA measures of government enterprise employment using Post Office and State and local government noneducational employment from the establishment survey as indicators for Federal and State and local enterprises. Average weekly hours for government workers, from the household survey, are used for government enterprises. The government class-of-worker category includes all civilian employees.

Nonprofit institutions

In order to bring employment data drawn from the establishment survey into conformity with the business sector concepts, employees of firms owned by nonprofit institutions are removed. Using BEA compensation data, factors are obtained by 2-digit SIC, representing the fraction of employment associated with nonprofit institutions. Hours of employees in nonprofit institutions are computed by dividing compensation expenditures of nonprofit firms by hourly industry compensation; these hours estimates are then divided by the average weekly hours appropriate to each industry to obtain employment in nonprofit institutions. The ratio of nonprofit employment to employment for the industry as a whole is the factor used to obtain monthly estimates of employment for nonprofit institutions from total industry employment in the monthly establishment survey. The latest available factor is used until new BEA annual data are available.

Appendix E. Comparison of Base-year-weighted and Tornquist Index Numbers of Multifactor Productivity

The measures of multifactor productivity introduced in this bulletin are computed using a Tornquist index aggregation procedure. Since this is the first time BLS has used this index number formula, a comparison was made of the results of this method and the more commonly used method of base-year weighting. This appendix presents the findings of this comparison .

As shown in appendix A, the index of aggregate inputs (labor and capital) is constructed from a weighted average of the growth rates of the separate inputs. The weights are an average of the relative cost shares of the input for the given and previous years. For a base-year-weighted index, the cost shares are held constant over the period of time. For this comparison, both an index using one set of weights for the complete series and an index using different weights for subperiods (hereafter referred to as a shifted base-year-weighted index) were constructed. For the constant-base-year-weight series, the 1972 cost shares were used, as this is the base year for the output index (GNP). As with the Tornquist index, the indexes of inputs for the base-year weighting method were calculated for the most disaggregated level possible. The detailed assets were aggregated to the corresponding sector level, and these sectors were then aggregated to conform to the final indexes. Hence, a single asset (commercial buildings, for example) within different sectors has different weights.

Annual percent changes

Tables E–1 through E–3 show the annual percent changes of multifactor productivity for the three published sectors (private business, private nonfarm business, and manufacturing) as calculated using the Tornquist index method, shifted base-year weights, and the same (1972) base-year weights for the complete series. Also shown are the differences in the percent changes for each method.

Tornquist vs. shifted base-year index. With the exception of a few years (1952 and 1965), there is little difference between the annual percent changes calculated using the Tornquist method and the shifted base-year index for the private business and private nonfarm business sectors. For the manufacturing sector, there are more years where the differences are large, and the magnitudes are also greater than for the other sectors. For all three sectors, the differences were virtually all negative prior to 1958, and almost all were positive and smaller after 1958. This indicates that, prior to 1958, multifactor productivity grew faster based on the shifted base-year-weighted index, than on the Tornquist method.

Tornquist vs. base-year index. The differences in the annual percent changes between the Tornquist index and the 1972 base-year-weighted indexes follow somewhat different patterns from the comparisons discussed above. The differences are greater in value for the private business and nonfarm business sectors, but not as large as for the manufacturing sector.

Average annual rates of growth

Table E–4 presents the average annual growth rates for the complete series, 1948–81, and the two subperiods 1948–73 and 1973–81. For the whole period, there is a significant difference in results of the different methods for each of the three sectors. The average annual growth rate based on the Tornquist index is 1.5 percent for private business, 1.3 percent for private nonfarm business, and 1.8 percent for manufacturing. Using shifted base-year weights, the annual growth rates for the sectors are 1.7 percent, 1.5 percent, and 2.0 percent, respectively. And, using 1972 base-year weights, the annual growth rates are 1.3 percent for private business, 1.0 percent for private nonfarm business, and 1.6 percent for manufacturing. In all sectors, the annual rate of growth based on the Tornquist index lies between the shifted base-year index and the 1972 base-year index.

The average annual growth rates for the two subperiods are less affected than those for the total period by the use of the different index number formulas. For 1973–81, the difference in growth rates is at most 0.1 percent. For the earlier period, differences are still present between the Tornquist method and the 1972 base-year-weighted method, but there is little difference between the Tornquist and shifted base-year method. Thus, the measured productivity slowdown after 1973 is not significantly changed by using shifted base-year weights rather than the Tornquist method.

Table E–1. Private business sector: Annual percent change in multifactor productivity under different index number methods, 1949–81

Year	Tornquist (1)	Shifted base-year weights[1] (2)	Difference, (1)–(2) (3)	1972 base year (4)	Difference, (1)–(4) (5)
1949	−1.1	−0.9	−0.2	−1.6	0.5
1950	7.2	7.5	−0.3	6.9	0.3
1951	2.4	2.5	−0.1	1.9	0.5
1952	1.8	2.2	−0.4	1.7	0.1
1953	2.6	2.8	−0.2	2.3	0.3
1954	−0.4	−0.2	−0.2	−0.8	0.4
1955	4.4	4.7	−0.3	4.0	0.4
1956	0.3	0.6	−0.3	−0.1	0.4
1957	0.9	1.2	−0.3	0.5	0.4
1958	0.7	0.9	−0.2	0.4	0.3
1959	4.0	4.2	−0.2	3.7	0.3
1960	0.6	0.5	0.1	0.3	0.3
1961	2.0	2.0	0.0	1.5	0.5
1962	3.6	3.6	0.0	3.2	0.4
1963	2.9	2.8	0.1	2.6	0.3
1964	3.6	3.5	0.1	3.3	0.3
1965	3.1	2.8	0.3	2.7	0.4
1966	1.9	1.8	0.1	1.6	0.3
1967	0.3	0.4	−0.1	0.2	0.1
1968	2.4	2.3	0.1	2.1	0.3
1969	−0.5	−0.6	0.1	−0.8	0.3
1970	−1.2	−1.2	0.0	−1.3	0.1
1971	2.2	2.2	0.0	2.1	0.1
1972	3.3	3.3	0.0	3.3	0.0
1973	2.4	2.4	0.0	2.3	0.1
1974	−3.8	−3.8	0.0	−3.9	0.1
1975	−0.2	−0.3	0.1	−0.3	0.1
1976	3.8	3.7	0.1	3.7	0.1
1977	3.0	3.0	0.0	2.9	0.1
1978	1.0	1.1	−0.1	0.9	0.1
1979	−1.1	−1.1	0.0	−1.2	0.1
1980	−2.2	−2.2	0.0	−2.2	0.0
1981	1.1	1.1	0.0	1.1	0.0

[1]The following base-year weights were used for the subperiods: 1948 weights for 1948–59; 1959 weights, 1959–69; 1969 weights, 1969–73; and 1973 weights, 1973–81.

Table E-2. Private nonfarm business sector: Annual percent change in multifactor productivity under different index number methods, 1949–81

Year	Tornquist (1)	Shifted base-year weights[1] (2)	Difference, (1)–(2) (3)	1972 base year (4)	Difference, (1)–(4) (5)
1949	−0.6	−0.3	−0.3	−1.2	0.6
1950	6.2	6.5	−0.3	5.7	0.5
1951	2.0	2.2	−0.2	1.4	0.6
1952	1.2	1.7	−0.5	1.1	0.1
1953	1.5	1.8	−0.3	1.2	0.3
1954	−0.6	−0.3	−0.3	−1.0	0.4
1955	4.4	4.7	−0.3	4.0	0.4
1956	−0.1	0.1	−0.2	−0.6	0.5
1957	0.4	0.7	−0.3	0.0	0.4
1958	0.0	0.3	−0.3	−0.2	0.2
1959	4.3	4.5	−0.2	4.0	0.3
1960	0.1	0.0	0.1	−0.3	0.4
1961	1.7	1.7	0.0	1.2	0.5
1962	3.5	3.4	0.1	3.1	0.4
1963	2.5	2.4	0.1	2.3	0.2
1964	3.5	3.3	0.2	3.1	0.4
1965	2.9	2.5	0.4	2.4	0.5
1966	1.7	1.5	0.2	1.3	0.4
1967	0.0	0.1	−0.1	−0.1	0.1
1968	2.4	2.3	0.1	2.2	0.2
1969	−0.8	−1.0	0.2	−1.1	0.3
1970	−1.6	−1.7	0.1	−1.8	0.2
1971	2.0	1.9	0.1	1.9	0.1
1972	3.5	3.5	0.1	3.5	0.0
1973	2.3	2.3	0.0	2.3	0.0
1974	−3.9	−3.9	0.0	−4.0	0.1
1975	−0.5	−0.6	0.1	−0.6	0.1
1976	3.8	3.7	0.1	3.2	0.1
1977	2.9	2.8	0.1	2.7	0.2
1978	1.1	1.1	0.0	1.0	0.1
1979	−1.5	−1.4	−0.1	−1.5	0.0
1980	−2.3	−2.3	0.0	−2.3	0.0
1981	0.7	0.7	0.0	0.7	0.0

[1]The following base-year weights were used for the subperiods: 1948 weights for 1948–59; 1959 weights, 1959–69; 1969 weights, 1969–73; and 1973 weights, 1973–81.

Table E-3. Manufacturing sector: Annual percent change in multifactor productivity under different index number methods, 1949–81

Year	Tornquist (1)	Shifted base-year weights[1] (2)	Difference, (1)-(2) (3)	1972 base year (4)	Difference, (1)-(4) (5)
1949	-0.4	0.4	-0.8	-0.7	0.3
1950	7.1	7.2	-0.1	6.7	0.4
1951	3.9	4.3	-0.4	3.6	0.3
1952	-0.1	0.9	-1.0	0.2	-0.3
1953	2.1	2.3	-0.2	1.8	0.3
1954	-2.0	-1.5	-0.5	-2.2	0.2
1955	5.8	6.1	0.3	5.6	0.2
1956	-1.6	-1.2	-0.4	-1.8	0.2
1957	0.4	0.8	-0.4	0.2	0.2
1958	-3.4	-3.1	-0.3	-3.6	0.1
1959	6.6	6.5	0.1	6.5	0.1
1960	0.1	0.0	0.1	0.0	0.1
1961	1.5	1.5	0.0	1.4	0.1
1962	5.1	5.0	0.1	5.0	0.1
1963	6.7	6.7	0.0	6.7	0.1
1964	4.6	4.5	0.1	4.5	0.1
1965	3.7	3.4	0.3	3.5	0.2
1966	1.2	0.9	0.3	1.0	0.2
1967	-2.3	-2.1	-0.2	-2.3	0.0
1968	2.4	2.4	0.0	2.3	0.1
1969	1.0	0.9	0.1	0.9	0.1
1970	-2.7	-2.8	0.1	-3.0	0.3
1971	4.5	4.5	0.0	4.3	0.2
1972	6.0	5.9	0.1	5.9	0.1
1973	6.3	6.2	0.1	6.3	0.0
1974	-3.9	-4.0	0.1	-4.1	0.2
1975	-0.9	-1.1	0.2	-1.5	0.6
1976	5.3	5.2	0.1	5.2	0.1
1977	3.0	2.9	0.1	.2.9	0.1
1978	1.0	1.1	-0.1	1.1	-0.1
1979	-0.1	0.0	-0.1	0.0	-0.1
1980	-2.4	-2.5	0.1	-2.6	0.2
1981	1.4	1.4	0.0	1.3	0.1

[1]The following base-year weights were used for the subperiods: 1948 weights for 1948–59; 1959 weights, 1959–69; 1969 weights, 1969–73; and 1973 weights, 1973–81.

Table E-4. Rates of growth of multifactor productivity under different index number methods by major sector, 1948–81

(Percent per year, compounded)

Sector and method	1948–81	1948–73	1973–81
Private business:			
Tornquist	1.5	2.0	0.1
Shifted base-year weights	1.7	2.0	0.2
1972 base-year weights	1.3	1.7	0.1
Private nonfarm business:			
Tornquist	1.3	1.7	0.0
Shifted base-year weights	1.5	1.8	0.0
1972 base-year weights	1.0	1.4	0.0
Manufacturing:			
Tornquist	1.8	2.2	0.4
Shifted base-year weights	2.0	2.3	0.3
1972 base-year weights	1.6	2.1	0.3

Appendix F. Comparison of Multifactor Measures

This appendix compares the BLS measures of multifactor productivity with those calculated by Edward Denison, Dale Jorgenson, and John Kendrick. These authors have been making estimates of productivity growth for many years and each has contributed significantly to the understanding of productivity measurement. The comparisons are drawn from the authors' latest published studies.[1]

The comparisons made within each of the following sections are subject to qualification: First, only the major differences in methodology and classification are discussed; second, the authors' latest published work may not incorporate the latest data revisions because of publication lags.

The comparisons are made on the basis of each of the separate factors used in the measurement of productivity—output, capital input, and labor input. Also included are the method of aggregation and the allocation of shares for the input factors. While not all aspects of productivity measurement fit precisely into these categories, they capture the major issues.

Output

The various authors include different factors in their output measures. These are explained below and compared in table F-1.

The BLS measure of output for multifactor productivity encompasses the private business sector of the economy. This definition represents the privately owned, profit-oriented enterprises in the economy. The measure for this sector is derived from the gross national product (GNP) measure. Specifically, private business output is equal to GNP less:

- statistical discrepancy
- owner-occupied housing
- rest of the world
- general government
- government enterprises
- nonprofit institutions
- household sector.

Table F-1. Computation of output measures by BLS, Denison, Jorgenson, and Kendrick

Measure	BLS	Denison	Jorgenson	Kendrick
GNP	X	X	X	X
Less:				
Statistical discrepancy	X	X		X
Owner-occupied housing	X	X		X
Tenant-occupied housing		X		
Rest of the world	X	X	X	X
General government	X	X	X	X
Government enterprises	X		X	X
Nonprofit institutions	X	X		X
Household sector	X	X		X
Capital consumption allowances		X		
Business transfer payments		X		
Indirect business taxes		X		
Federal indirect business taxes			X	
State and local indirect business taxes			X	
Plus:				
Services of consumer durables			X	
Services of durables held by institutions			X	
Net rent on institutional real estate			X	
Capital stock tax			X	
Business motor vehicle taxes			X	
Other business taxes			X	
Subsidies less surplus of government enterprises (Federal, State, and local)		X	X	

This output measure was 76 percent of GNP in 1972. (The Bureau of Economic Analysis used 1972 as its constant-dollar base year for output measurement.)

Denison measures output for the nonresidential business sector. While the coverage is similar to the BLS measures, Denison starts from national income (NI) instead of GNP.

[1]Edward F. Denison, *Accounting for Slower Economic Growth: the United States in the 1970's* (Washington, The Brookings Institution, 1979), and ''Accounting for Slower Economic Growth: An Update,'' paper presented at the Conference on International Comparisons of Productivity and Causes of the Slowdown held by the American Enterprise Institute, Washington, Sept. 30, 1982; Barbara M. Fraumeni and Dale F. Jorgenson, ''The Role of Capital in U.S. Economic Growth, 1948–1976,'' and Dale Jorgenson, ''Accounting for Capital,'' both in George von Furstenberg, ed., *Capital, Efficiency and Growth* (Cambridge, Mass., Ballinger Publishing Co., 1980); and John Kendrick and Elliot S. Grossman, *Productivity in the United States* (Baltimore, The Johns Hopkins University Press, 1980). Kendrick's and Grossman's data are updated quarterly in *Multiple Input Productivity Indexes* (Houston, The American Productivity Center).

NI is equal to GNP less:

- statistical discrepancy
- capital consumption allowances
- business transfer payments
- indirect business taxes.

Nonresidential business output is equal to NI less:

- owner-occupied housing
- rest of the world
- general government
- nonprofit institutions
- household sector
- tenant-occupied housing.

This measure of output was 76 percent of NI and 62 percent of GNP in 1972. The major differences between the BLS and Denison measures of output are that he includes government enterprises and excludes capital consumption allowances (depreciation), business taxes and transfers, and tenant-occupied housing.

Jorgenson's measure of output encompasses the sector labeled gross private domestic product. In general, this measure covers all private concerns including households and nonprofit institutions. In order to calculate output for this sector, services from the capital stock of households and nonprofit institutions are estimated. The income generated by these services is then estimated and added to the basic output measure. Hence, Jorgenson's measure of output is larger than any of the others. For 1972, his output measure was over 92 percent of GNP. It is calculated by subtracting from GNP:

- rest of the world
- general government
- Federal indirect business taxes
- State and local business taxes;

and adding:

- services of consumer durables
- services of durables held by institutions
- net rent on institutional real estate
- capital stock tax
- business motor vehicle licenses
- business property taxes
- other business taxes.

Kendrick's measure of output is derived directly from the industry measures of output computed from the 14 component gross product originating (GPO) measures. Theoretically, the GPO measures by industry should be equal to the published GNP. In practice, however the GPO measure falls short of the GNP by a slight but significant amount.

This measure is approximately equal to the GNP less the same factors which BLS subtracts:

- statistical discrepancy
- owner-occupied housing
- rest of the world
- general government
- government enterprises
- nonprofit institutions
- household sector.

For 1972, Kendrick's measure was 84 percent of GNP in current dollars. Table F–2 lists the indexes and long-term growth rates for each of the output measures described above.

The measures are also depicted in chart F–1. As is evident from the chart, there is little difference over the postwar period in any of the output measures. Denison's measure is the lowest; however, all the growth rates are about the same. For most of the period, Jorgenson's measure is the highest, but his growth rates differ from Denison's by only 0.2 percent over the 1948–73 period.

Table F–2. Indexes and rates of growth of output for the most aggregate sector measured by BLS, Denison, Jorgenson, and Kendrick, 1948–81

Period	BLS	Denison	Jorgenson	Kendrick
	Index, 1972=100			
1948	42.8	44.4	39.3	43.2
1949	42.0	43.0	39.6	42.3
1950	45.9	47.2	43.5	46.3
1951	48.6	50.1	46.5	49.0
1952	50.3	51.7	48.1	50.6
1953	52.5	54.0	50.4	52.7
1954	51.5	52.5	49.9	51.7
1955	55.7	57.0	53.7	55.9
1956	57.2	58.3	54.9	57.3
1957	57.8	58.7	55.8	57.9
1958	56.8	57.3	55.9	57.0
1959	61.0	61.9	59.2	60.1
1960	61.9	62.7	60.4	62.2
1961	63.0	63.6	61.9	63.2
1962	66.5	67.3	65.5	66.7
1963	69.4	70.4	68.1	69.6
1964	73.6	74.8	71.9	73.8
1965	78.6	80.2	76.5	78.8
1966	82.9	84.8	81.3	83.1
1967	84.8	86.2	83.5	84.9
1968	89.2	90.5	87.5	89.2
1969	91.7	92.8	90.5	91.9
1970	91.0	91.1	90.5	91.1
1971	93.7	93.7	94.1	93.9
1972	100.0	100.0	100.0	100.0
1973	106.6	107.0	106.4	106.7
1974	104.4	103.8	105.4	104.6
1975	102.3	100.6	104.7	102.7
1976	108.9	107.5	111.0	109.2
1977	116.2	115.1	117.7	116.0
1978	122.6	121.7	123.7	121.5
1979	125.3	124.1	127.1	124.9
1980	123.4	120.8	126.4	124.1
1981	126.5	123.8	129.3	126.5
	Rate of growth (annual percent change)			
1948–73	3.7	3.6	4.1	3.7
1973–81	2.2	1.8	2.5	2.2
1948–81	3.3	3.2	3.7	3.3

SOURCES: Bureau of Labor Statistics; Edward F. Denison, *Accounting for Slower Economic Growth: The United States in the 1970's* (Washington, The Brookings Institution, 1979); Dale F. Jorgenson, Harvard University, Cambridge, Mass.; John F. Kendrick, in *Multiple Input Productivity Indexes*, Vol. 3, No.1, September 1982 (Houston, The American Productivity Center).

Chart F-1. Output for the most aggregate sector measured by BLS, Denison, Jorgenson, and Kendrick, 1948-81

(Index, 1948 = 100)

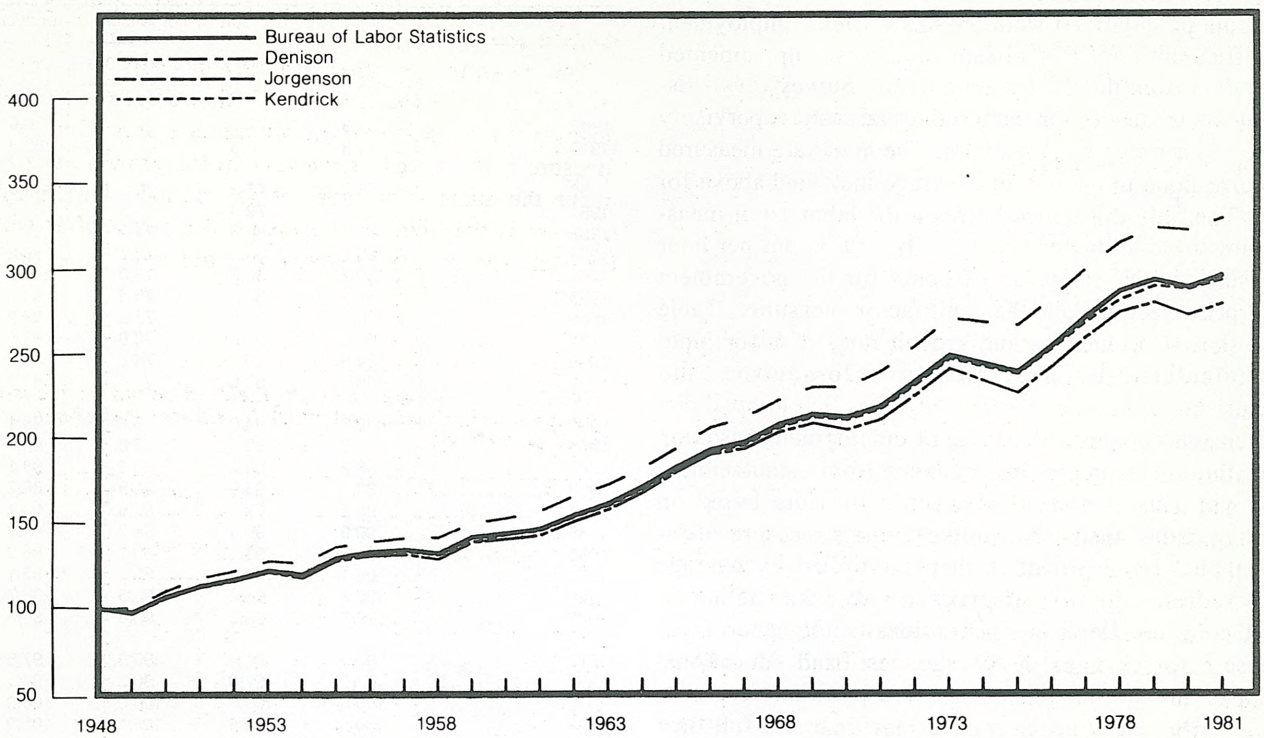
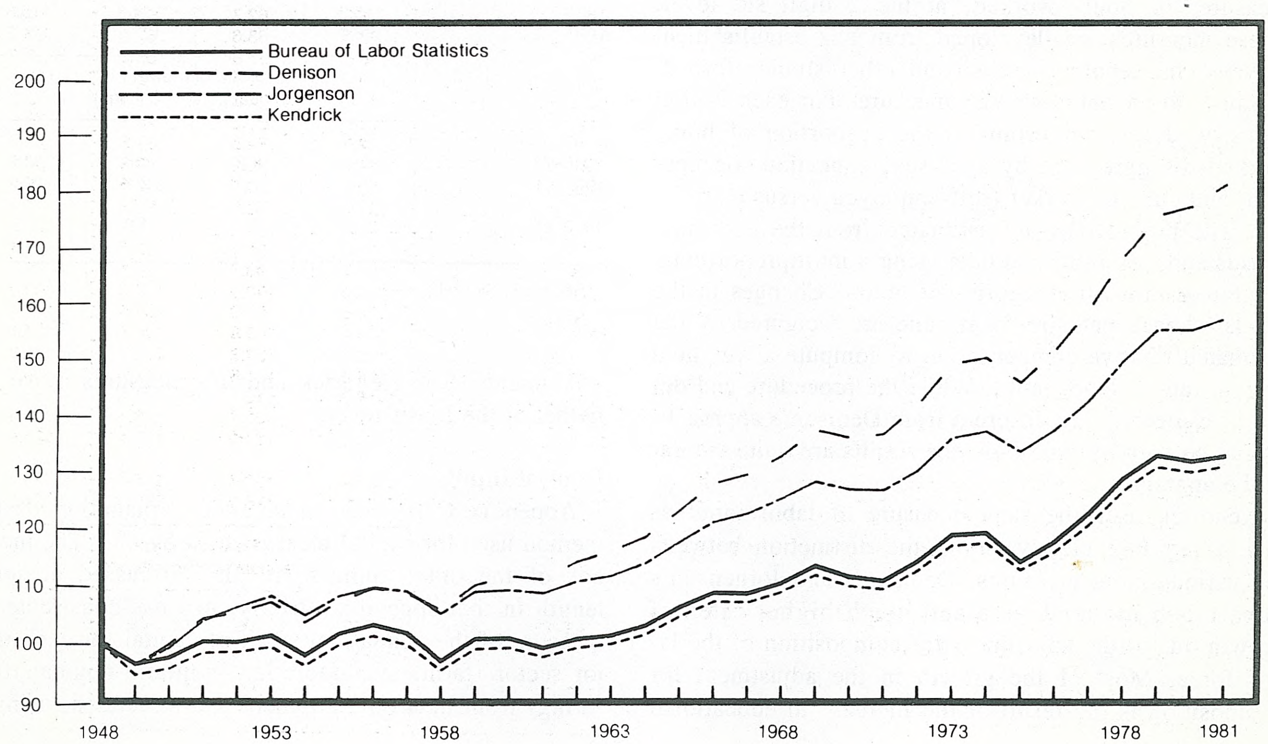


Chart F-2. Labor input for the most aggregate sector measured by BLS, Denison, Jorgenson, and Kendrick, 1948-81

(Index, 1948 = 100)



Labor input

A detailed explanation of BLS's measure of labor input is provided in appendix D. Labor input is a measure of hours paid derived from the BLS Current Employment Statistics program (establishment survey) supplemented with data from the Current Population Survey (CPS). Estimates are made for nonproduction and supervisory workers' average weekly hours. The hours are measured to correspond to the output coverage indicated above for BLS. The only difference between the labor input measure for the multifactor productivity and output per hour measures is the exclusion of hours for the government enterprise sector from the multifactor measures. Table F–3 shows the indexes and growth rates of labor input as calculated by BLS, Denison, Jorgenson, and Kendrick.

Denison computes the level of employment based on both the CPS estimates and changes from establishment surveys. This is done to develop a measure based on persons rather than jobs, unlike the BLS measure of labor input. Employment is then multiplied by average hours adjusted to an hours-worked rather than an hours-paid concept. Denison further adjusts the labor input measure for changes in the age, sex, and educational composition of the work force. Adjustments are also made for changes in the mix of part-time and full-time employment. The changes in age, sex, and education cause this measure of labor input to grow significantly faster than the BLS measure.

Jorgenson measures labor input starting with the BEA measures of hours worked, at the 2–digit SIC level. These measures are developed from BLS establishment surveys, household surveys, and other studies for adjustment to an hours-worked measure. For each 2-digit industry, Jorgenson estimates the proportion of hours worked disaggregated by age, sex, education, occupation, and class of worker (self-employed versus employee). The proportions are estimated from the decennial census and CPS published data using a multiproportional assumption for all categories of hours. Changes in the levels of each category over time are weighted by the estimated relative compensation to compute a weighted growth rate of labor input. While the procedure and detail of categories are different from Denison's approach, as can be seen in table F–4, the results are quite similar at the aggregate level.

Kendrick uses the same measure of labor input as BLS. Chart F–2 clearly shows the distinction between the various input measures. Denison's and Jorgenson's have much higher levels and much higher rates of growth due to the adjustment for composition of the labor force. Most of the growth in the adjustment for composition is the result of the increase in educational attainment.[2] The Kendrick and BLS measures move together at the lower level.

Table F–3. Indexes and rates of growth of labor input for the most aggregate sector measured by BLS, Denison, Jorgenson, and Kendrick, 1948–81

Period	BLS	Denison	Jorgenson	Kendrick
	Index, 1972=100			
1948	87.3	76.7	70.3	88.6
1949	84.3	74.0	67.7	83.8
1950	85.3	76.2	70.3	84.8
1951	87.8	79.9	73.5	87.3
1952	87.7	81.6	74.2	87.4
1953	88.7	83.2	75.5	88.2
1954	85.7	80.6	73.0	85.3
1955	87.0	83.2	75.6	88.5
1956	90.3	84.3	77.2	89.9
1957	89.0	83.8	76.6	88.5
1958	84.8	80.8	74.5	84.6
1959	88.2	83.8	77.6	87.0
1960	88.3	84.0	78.7	88.1
1961	86.8	83.6	78.3	86.7
1962	88.2	85.2	80.5	88.1
1963	88.7	85.9	81.8	88.7
1964	90.2	87.6	83.5	90.1
1965	90.3	90.4	86.7	92.9
1966	95.2	93.1	90.1	95.2
1967	95.1	94.2	91.2	95.1
1968	96.7	96.2	93.5	96.7
1969	99.3	98.5	96.8	99.3
1970	97.6	97.4	95.8	97.6
1971	97.0	97.3	96.3	97.1
1972	100.0	100.0	100.0	100.0
1973	104.0	104.5	105.1	103.9
1974	104.3	105.4	105.8	104.3
1975	99.9	102.6	102.7	100.1
1976	103.0	105.6	106.7	102.9
1977	107.3	109.6	111.9	107.1
1978	112.6	115.0	118.4	112.3
1979	116.2	119.3	123.7	116.1
1980	115.3	119.2	124.8	115.3
1981	116.1	120.8	127.5	116.2
	Rate of growth (annual percent change)			
1948–73	0.7	1.2	1.6	0.6
1973–81	1.4	1.8	2.4	1.4
1948–81	0.9	1.4	1.8	0.8

SOURCES: See table F–2.

Capital input

Appendix C provides a detailed explanation of the method used for capital measurement by BLS. The methods of the other authors are also discussed at some length in that appendix. Briefly, BLS has constructed a measure of the annual net stock of capital for each major sector (farm, manufacturing, nonfarm-nonmanufacturing) from data on equipment and structures, using a

[2]See Denison, *Accounting for Slower Economic Growth*, pp. 160–169.

Table F–4. Computation of labor input measures by BLS, Denison, Jorgenson, and Kendrick

Measure	BLS	Denison	Jorgenson	Kendrick
Hours paid	X			X
Hours worked		X	X	
Plus adjustments for:				
Age		X	X	
Sex		X	X	
Education		X	X	
Occupation			X	
Industry			X	
Employee versus self-employed		X	X	
Full- versus part-time workers		X		

variable decay function. Assets are aggregated using a weighted average of the growth rates of the separate assets. The weights are equal to the relative service prices, or user prices, of the different assets. The estimates for each of the sectors are aggregated to the published measures. Included in the capital input measure are estimates for the quantities of land and inventories, which are also weighted by their respective user prices. The annual flows of services of capital are assumed proportional to the annual stocks of capital; this assumption is used by the other authors as well.

Denison constructs his estimates of capital input directly from the BEA estimates of net and gross capital stock. BEA net capital stock is based on straight-line depreciation; gross capital includes no depreciation or decay. Both measures are based on asset prices rather than rental prices. Denison combines the two measures of stocks, weighting gross by 0.75 and net by 0.25.

Jorgenson's construction of capital input begins with estimates of investment for equipment and structures, land, and inventories all classified by 46 industry groupings and 4 different legal forms of organization. As described in appendix D, BLS has generally followed Jorgenson's method of capital measurement. The major difference is in the decay function: Jorgenson uses a constant decay rate and BLS uses a variable decay rate. Another major difference is that BLS focuses on asset detail of capital and Jorgenson concentrates on industry detail.

Kendrick uses the gross capital stocks of equipment and structures estimated by BEA for their wealth accounts. He adds measures of land and inventories, as do the other researchers. Table F–5 displays the different measures of capital input. Chart F–3 also shows how the capital measures differ. The Jorgenson measure is the highest and also has the fastest rate of growth. Kendrick's measure, on the other hand, is the lowest. The Denison and BLS measures move similarly. Table F–6 summarizes the procedures of the various researchers in computing their capital input measures.

Table F–5. Indexes and rates of growth of capital input for the most aggregate sector measured by BLS, Denison, Jorgenson, and Kendrick, 1948–81

Period	BLS	Denison	Jorgenson	Kendrick
	Index, 1972=100			
1948	43.6	42.1	35.8	48.5
1949	45.3	43.4	38.3	49.3
1950	47.0	44.8	40.0	50.9
1951	49.0	47.5	42.9	52.7
1952	51.1	49.8	95.4	54.0
1953	52.6	51.3	47.1	55.2
1954	54.1	52.5	49.1	56.3
1955	55.8	54.1	50.8	58.4
1956	57.8	56.2	53.7	60.1
1957	59.6	57.9	56.1	61.8
1958	60.9	59.1	58.2	63.0
1959	62.0	60.5	59.2	64.8
1960	63.5	62.1	61.3	66.5
1961	64.9	63.7	63.1	68.5
1962	66.4	65.4	64.6	70.1
1963	68.3	67.6	66.8	72.2
1964	70.6	70.0	69.5	74.8
1965	73.7	73.1	72.6	77.8
1966	77.5	77.2	76.7	81.1
1967	81.6	81.5	81.2	84.3
1968	85.4	85.3	85.0	87.5
1969	89.3	89.4	89.0	91.0
1970	93.2	93.1	93.2	93.8
1971	96.5	96.4	96.3	96.7
1972	100.0	100.0	100.0	100.0
1973	104.6	104.7	105.3	104.3
1974	109.3	109.8	111.5	107.8
1975	112.3	113.0	115.5	110.2
1976	114.4	115.6	117.6	113.3
1977	117.4	119.4	121.3	117.1
1978	121.6	124.5	126.6	121.0
1979	126.2	129.8	132.7	125.5
1980	130.7	134.1	138.3	129.4
1981	134.4	138.3	141.6	133.0
	Rate of growth (annual percent change)			
1948–73	3.6	3.7	4.4	3.1
1973–81	3.2	3.5	3.8	3.1
1948–81	3.5	3.7	4.3	3.1

SOURCES: See table F–2.

Table F–6. Computation of capital input measures by BLS, Denison, Jorgenson, and Kendrick

Characteristic	BLS (hyperbolic decay function)	Denison (3 parts gross; 1 part net)	Jorgenson (geometric)	Kendrick (gross)
Weights:				
Asset prices		X		X
Rental prices	X		X	
Aggregation of assets:				
Fixed weighted		X		X
Variable weighted	X		X	

Chart F-3. Capital input for the most aggregate sector measured by BLS, Denison, Jorgenson, and Kendrick, 1948-81

(Index, 1948 = 100)

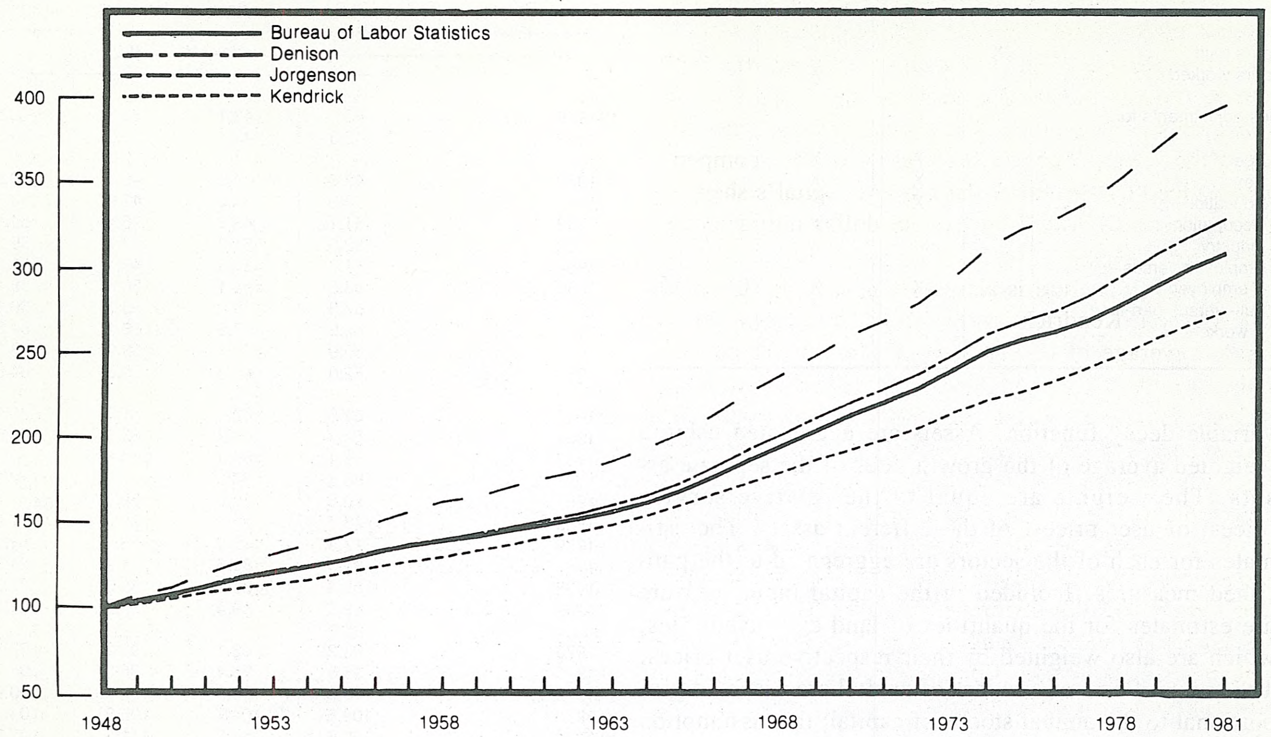
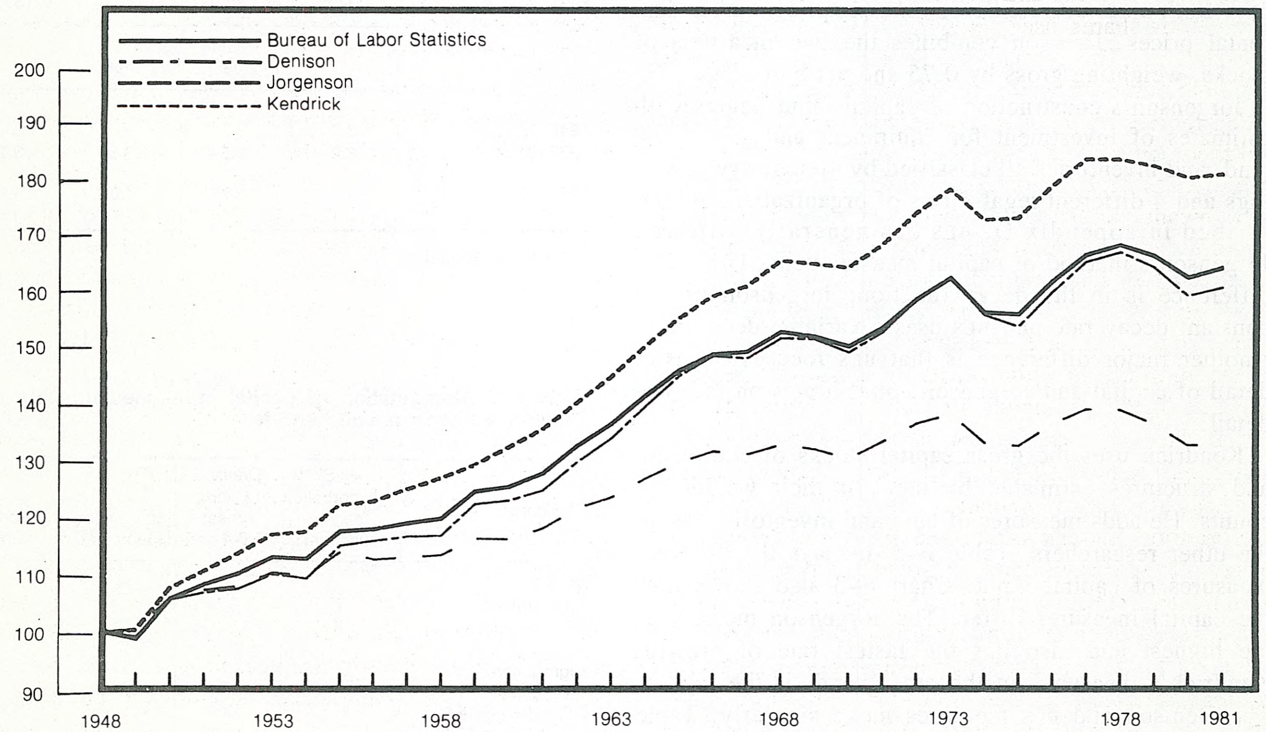


Chart F-4. Multifactor productivity for the most aggregate sector measured by BLS, Denison, Jorgenson, and Kendrick, 1948-81

(Index, 1948 = 100)



Aggregation

The BLS procedure for aggregating the inputs (labor and capital) to form a combined input is a variable weighted index method, called a Tornquist index. It is formed by taking a weighted average of the growth rates of the individual inputs. The weights are averages of the given year's and previous year's relative cost share for each of the inputs. Labor's share is total labor compensation divided by current-dollar output; capital's share is property income divided by current-dollar output, or 1 minus labor's share.

The above procedure is also the one used by Denison and Jorgenson. Kendrick, on the other hand, computes a weighted average of the indexes of the various inputs, not the growth rate. Furthermore, he holds the weights (the cost shares) constant for different periods: 1948 shares are used for the period 1948–59; 1959 shares for the period 1959–69; 1969 shares for 1969–73; and 1973 shares for the period 1973 and after. This method is much more restrictive than the method used by BLS and the others in that it assumes that the relationship between output and the different inputs remains constant with respect to relative changes in the input prices. That is, increases in the price of one input would not cause a change in the usage of that input.

Labor and capital shares

The major difference, however, among the different measures of productivity is not the method of aggregation as much as it is the definition and construction of the shares (both labor and capital). Table F–7 shows the annual labor shares used by BLS, Denison, Jorgenson, and Kendrick. The primary reasons for the differences are (1) the output measure, (2) the procedure used to allocate proprietors' income (which contains both returns from labor and capital) between returns to labor and returns to capital, and (3) treatment of capital consumption allowances. Denison measures output net of capital consumption allowances. BLS, Jorgenson, and Kendrick include capital consumption allowances in output and also as part of the cost of capital in the production of output. Hence, in these measures, income from capital is a larger share of output than in Denison's measure. Jorgenson further estimates the capital services and returns to these services for the household and nonprofit institutional sectors. These estimates further increase his measure of capital's share.

Proprietors' income is derived from both returns to capital and returns to labor. In order to compute the labor and capital shares, proprietors' income has to be allocated between the two different sources. The method developed by BLS is described in appendix D. Briefly, for the manufacturing and nonfarm nonmanufacturing sectors, BLS assumes the corporate rates of return for proprietors' capital and employee compensation per hour for proprietors' labor and applies the resulting

Table F–7. Labor's share for the most aggregate sector measured by BLS, Denison, Jorgenson, and Kendrick, 1948–81

(Percent)

Year	BLS	Denison	Jorgenson	Kendrick
1948	62.2	78.3	61.9	63.9
1949	64.2	78.2	61.7	63.9
1950	61.3	78.1	60.0	63.9
1951	61.8	78.6	59.3	63.9
1952	64.8	79.4	60.1	63.9
1953	66.4	79.8	61.6	63.9
1954	66.1	80.3	59.9	63.9
1955	63.3	80.9	59.4	63.9
1956	63.9	81.2	60.9	63.9
1957	64.6	81.3	61.4	63.9
1958	64.6	81.7	59.5	64.3
1959	63.5	82.0	59.9	64.3
1960	63.6	81.9	60.1	64.3
1961	62.9	81.6	59.3	64.3
1962	62.2	81.3	58.9	64.3
1963	61.4	80.6	58.7	64.3
1964	61.6	79.8	58.4	64.3
1965	60.9	79.2	57.1	64.3
1966	61.8	79.1	56.9	64.3
1967	62.5	79.2	57.7	64.3
1968	62.9	79.9	58.3	64.3
1969	64.5	80.7	58.8	65.1
1970	65.8	81.5	60.3	65.1
1971	65.0	82.0	59.1	65.1
1972	65.6	82.3	57.9	65.1
1973	65.0	82.5	57.2	68.8
1974	66.4	82.7	59.6	68.8
1975	63.8	82.7	58.6	68.8
1976	63.9	82.6	58.0	68.8
1977	63.3	82.7	57.0	68.8
1978	64.3	82.8	57.4	68.8
1979	65.4	82.3	58.5	68.8
1980	65.5	83.0	60.1	68.8
1981	64.6	83.2	60.7	68.8

SOURCES: See table F–2.

prices to proprietors' capital and labor services (hours). Since the sum of these estimates more than exhausts the reported proprietors' income, these initially estimated payments to each factor are proportionately reduced so that the sum is equal to the NIPA estimates of proprietors' income. For the farm sector, the corporate rate of return to capital is imputed to the farm capital. The capital income is then calculated and subtracted from the proprietors' income, the remainder being the labor income.

Denison allocates proprietors' income in a similar manner. The major difference is that business sector rates of return to capital and compensation per hour are applied to the farm sector's hours and capital. The computed income is then reduced by a constant ratio for all the factors, both labor and tangible assets.

Jorgenson, on the other hand, imputes the corporate rate of return of capital to proprietors' capital for each sector. This imputation is made at a more detailed industry level than that used by BLS or Denison. Capital income is then subtracted from proprietors' income and the residual is allocated to labor income at the industry level. This method of allocation further increases capital's share relative to labor's because very little is left of proprietors' income after subtracting capital income.

Kendrick imputes the employee hourly compensation to proprietors and the self-employed for the base years for which he computes weights. The imputed hourly compensation is multiplied by estimated proprietors' hours and added to labor compensation to obtain labor's share. Capital's share is obtained by subtracting labor's share from unity.

Table F–8 lists the indexes and average annual growth rates of multifactor productivity calculated by BLS and other researchers. The implications of the different methods are readily apparent from the table and from chart F–4. The growth in output for the period 1948–73 is almost the same for each of the different methods but the growth in productivity is different: The differences arise because of the definitions of the inputs and the definition of the factor shares.

Jorgenson's method attributes most of the growth of output to the growth of inputs; therefore productivity growth is the smallest for his measure. Kendrick, on the other hand, attributes more growth of output to productivity growth than to input growth. The two major reasons are that he uses a gross rather than a net capital stock measure and also because he, like BLS, uses an unweighted hours measure for labor input, which has a slower rate of growth. Because the level of the gross capital stock measure is, in general, much higher than the net measure, the additional increment from annual investment does not increase the stock relatively as much. Hence his measure of capital services grows much more slowly during an expansion than a measure using net stocks.[3]

The BLS and Denison measures of multifactor productivity lie between Jorgenson's and Kendrick's measures. The reasons for this are different, however. As pointed out above, Denison's method of output measurement (net of capital consumption) shifts the weight towards labor and away from capital. However, even after adjusting for changes in composition, labor does not grow as fast as capital, so the slower growing input has the much larger weight. BLS does not make the adjustment for labor force composition, but attributes a larger share of growth to the faster growing input (capital) and coincidentially obtains almost the identical total input growth as Denison.

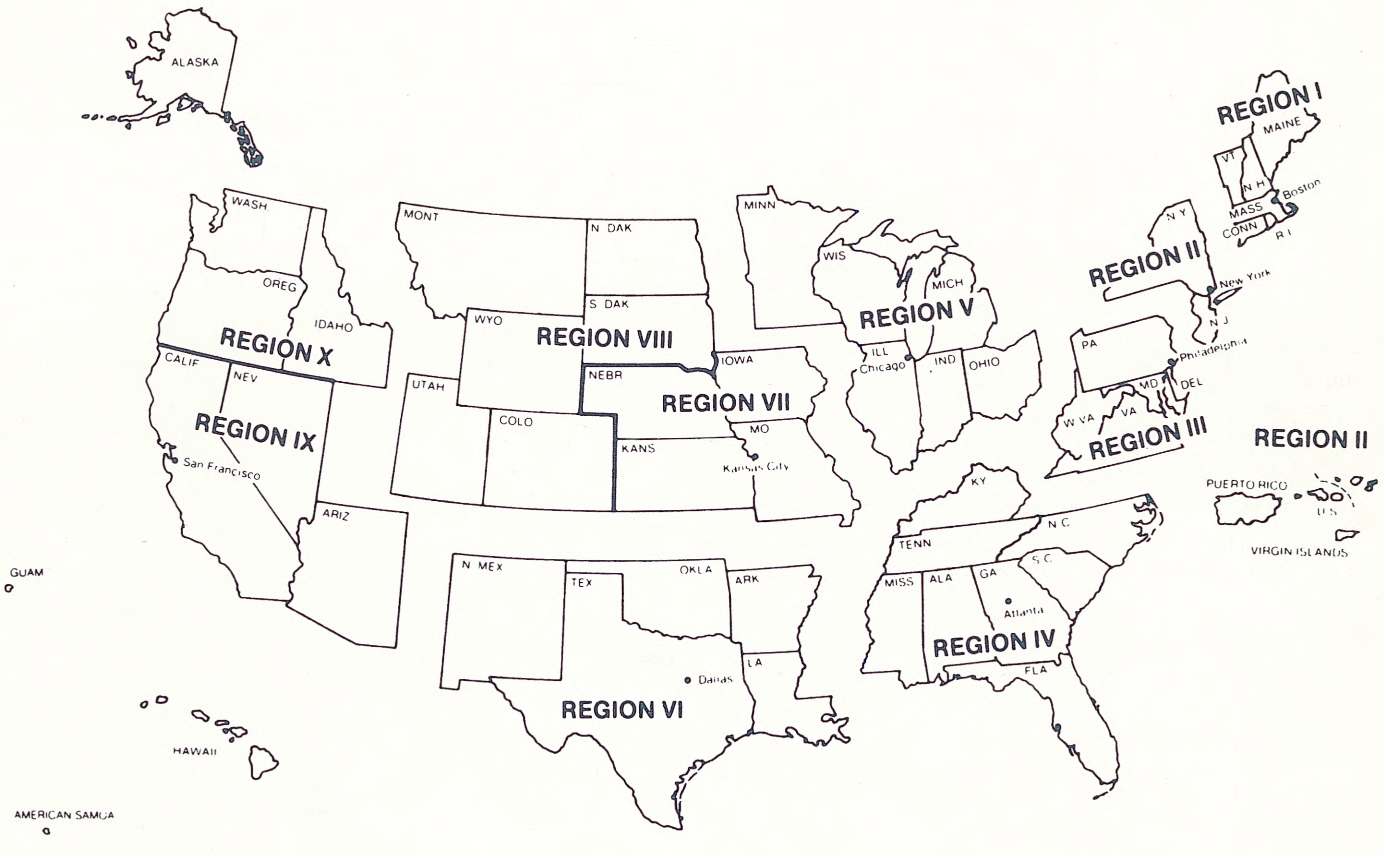
Table F–8. Indexes and rates of growth of multifactor productivity for the most aggregate sector measured by BLS, Denison, Jorgenson, and Kendrick, 1948–81

Period	BLS	Denison	Jorgenson	Kendrick
	Index, 1972=100			
1948	63.1	63.1	73.2	57.5
1949	62.3	62.5	73.6	57.8
1950	66.8	66.7	77.6	62.0
1951	68.4	67.5	78.6	63.7
1952	69.6	67.9	79.1	65.5
1953	71.4	69.5	80.8	67.4
1954	71.2	69.0	80.4	67.7
1955	74.3	72.7	83.5	70.4
1956	74.5	73.2	82.5	70.8
1957	75.2	73.7	82.8	72.0
1958	75.7	73.8	83.1	73.1
1959	78.7	77.3	85.2	74.4
1960	79.2	77.7	85.1	76.2
1961	80.7	78.8	86.5	78.0
1962	83.7	81.9	89.1	80.6
1963	86.1	84.5	90.5	83.2
1964	89.2	88.0	92.9	86.3
1965	92.0	91.4	95.0	89.2
1966	93.8	93.6	96.4	91.5
1967	94.1	93.3	96.0	92.5
1968	96.3	95.6	97.3	95.1
1969	95.8	95.5	96.7	94.8
1970	94.7	94.0	95.5	94.4
1971	96.8	96.3	97.7	96.7
1972	100.0	100.0	100.0	100.0
1973	102.4	102.5	101.2	102.5
1974	98.5	98.2	97.5	99.3
1975	98.3	96.9	97.1	99.5
1976	102.0	100.8	99.9	102.8
1977	105.0	104.2	101.8	105.6
1978	106.1	105.3	101.7	105.6
1979	104.9	103.6	99.9	104.9
1980	105.2	100.4	97.2	103.7
1981	103.6	101.4	97.2	104.1
	Rate of growth (annual percent change)			
1948–73	2.0	2.0	1.3	2.3
1973–81	0.1	−0.1	−0.5	0.2
1948–81	1.5	1.4	0.9	1.8

SOURCES: See table F–2.

[3]In the short run, gross capital can also grow faster than net capital when the investment rate is declining.

Bureau of Labor Statistics Regional Offices



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