Why Has Productivity Growth Declined? Productivity and Public Investment

Alicia H. Munnell

Senior Vice President and Director of Research, Federal Reserve Bank of Boston. *The author would like to thank Leah Cook and James Clark for able research assistance and colleagues at the Boston Fed for useful comments and suggestions.*

The decline in United States productivity has been widely identified as one of the major economic problems facing the nation. This concern is understandable; productivity growth is the major determinant of the future standard of living. If the efficiency with which resources can be used rises at 2.5 percent per year, people can expect their real wages and their living standards to double every 28 years, or roughly once a generation. In contrast, productivity growth of 0.5 percent means that children can expect living standards only 15 percent higher than those of their parents. In this regard, the numbers look bad: labor productivity growth in the private nonfarm business sector declined from an average annual rate of 2.5 percent over 1948–69 to 2.0 over 1969–73, and to 0.5 percent from 1973 to 1979. The recent numbers are somewhat better in that labor productivity growth has averaged 1.2 percent annually since 1979, but they are still well below the heights of the post–World War II period.

Economists have written extensively on the decline in productivity growth and have gone to great lengths to try to identify the reasons for the slowdown. No one has discovered a "silver bullet," and almost all observers end up concluding that a variety of factors have contributed to the observed phenomenon. The usual suspects include the effects of the changing composition of the labor force due to the influx of teenagers and other less experienced workers; a slowing in the rate of growth of the capital-labor ratio as investment in equipment and structures failed to keep pace with the unprecedented increase in the employed labor force; a leveling-off in research and development expenditures; the diversion of investment funds to pollution abatement; the maturation of some industries, with little new technology; and changes in attitudes towards work.

In a particularly interesting article, David Aschauer (1989) recently identified a new potential culprit in the slowdown of productivity growth. Aschauer introduces the obvious, but heretofore neglected, notion that the stock of public infrastructure as well as the stock of private capital may be a key to explaining changes in output from the private sector. His results, which show a strong relationship between output per unit of private capital and the stock of public capital, suggest that the decline in labor productivity and multifactor productivity in the 1970s may be attributable in very considerable part to the near cessation of investment in public infrastructure.

This study builds upon Aschauer's insight and explores whether changes in the amount of public capital, combined with the growth of private capital and labor, can explain most of the slowdown without appealing to a host of other factors. An additional motive, however, is to bring both the author and the reader up to date with what has been going on in the productivity area. For this reason, the article begins with a description of what is meant by productivity and an explanation of why productivity is important. The second section summarizes what has happened to various measures of productivity over the postwar period. The third section describes some of the most commonly cited reasons for the slowdown in productivity growth in the 1970s. The fourth section attempts to see whether the demographic adjustment to the labor input and the addition of public infrastructure as a capital input can explain the slowdown simply in terms of the fundamentals of the production function.

The final section speculates about the impact of future demographic and government spending developments on productivity during the 1990s. The conclusion is that the main causes of the productivity slowdown could possibly be behind us, as long as public infrastructure receives badly needed attention. Adequate public investment combined with the slow growth of the labor force should return us, if not to the spectacular post–World War II levels, then at least to twentieth century averages.

I. What Is Productivity and Why Does It Matter?

In the most general sense, productivity is a concept that measures the ratio of outputs to inputs; productivity increases if the same quantity of inputs—land, labor, and capital—produces more output. The simplest and most easily accessible productivity measure is labor productivity, which is the ratio of inflation-adjusted output to hours worked. The difficulty with this concept is that labor can increase output either by using more capital or by incorporating technical change; hence labor productivity does not permit the clear separation of the contribution to growth between increased quantities of factor inputs and the more efficient use of these inputs.

The measure that separates out the contribution to growth that results solely from improved technology or better management is multifactor productivity. The growth in this measure is calculated by subtracting from the growth in total output the direct contributions from increased amounts of capital and labor. Growth not attributed to factor inputs is then defined as multifactor productivity. Although multifactor productivity is a purer concept, it requires precise assumptions about a production function and how labor and capital are compensated, is difficult to calculate, and often is not available on an international basis. Given these problems and the fact that both productivity measures move together, labor productivity remains a useful concept.

A permanent decline in productivity growth would indeed be a source of serious concern.[1] Productivity growth is the major determinant of the increase in real wages and therefore living standards; hourly compensation adjusted for changes in purchasing power has risen at about the same rate as output per hour (chart 1). If output increases not because of productivity growth but only because more inputs are used in production, all the additional output is needed to pay the suppliers of the additional inputs at their old rates of compensation.

Productivity growth is the major determinant of the increase in real wages and therefore living standards.

Hence, in the absence of productivity growth, the only way that workers receive higher real wages is to work more hours. On the other hand, with productivity growth, the ratio of output to inputs rises and the factors of production find that they are compensated at higher real rates, as the prices for goods and services rise less rapidly than nominal wages and profits.

The increased affluence produced by productivity growth is valuable not only because it allows for

How Productivity Is Measured

Both concepts of productivity—labor productivity and multifactor productivity—can be demonstrated in terms of the traditional production function, an equation that relates the amount of outputs that can be achieved with given inputs. The most common formulation of the production function is as follows:

(1) $Q(t) = MFP(t)*f[K(t),L(t)]$,

where: $Q(t)$ = real output
$MFP(t)$ = index of multifactor productivity or technological progress
$K(t)$ = real capital input
$L(t)$ = real labor input.

To express this relationship in terms of growth over time involves taking the differential with respect to time and rearranging the terms to yield:[2]

(2) % Q growth = % MFP growth + s_k % K growth + s_l % L growth.

The weights, s_k and s_l, are the output elasticities of factor inputs. In other words, the weight s_l indicates how much output would increase for a given change in labor input. If some further assumptions are made about factor markets and the nature of the production function, the weights can be defined more precisely. Specifically, if factor markets are assumed to be perfectly competitive, so that factors are paid their marginal product, and if the production function exhibits constant returns to scale, so that a 10 percent increase in capital and labor leads to a 10 percent increase in output, then the weights equal the relative share of total income paid to capital and labor, respectively.[3]

Equation (2) is the basic relationship for computing the growth in multifactor productivity. It shows the growth in output to be equal to a weighted average of capital and labor inputs plus the growth in multifactor productivity. Alternatively, rearranging the terms, the growth in multifactor productivity is equal to the growth rate of output less the growth of an index of inputs (equation (3)). (Remember that the difference between two growth rates is equivalent to the growth rate of the ratio of the two variables.) Hence, multifactor productivity is similar to labor productivity in that it is computed as the ratio of output to input. The difference is that in the case of multifactor productivity, the input is an index of two factors, capital and labor.

(3) % MFP growth = % Q growth − s_k % K growth − s_l % L growth.

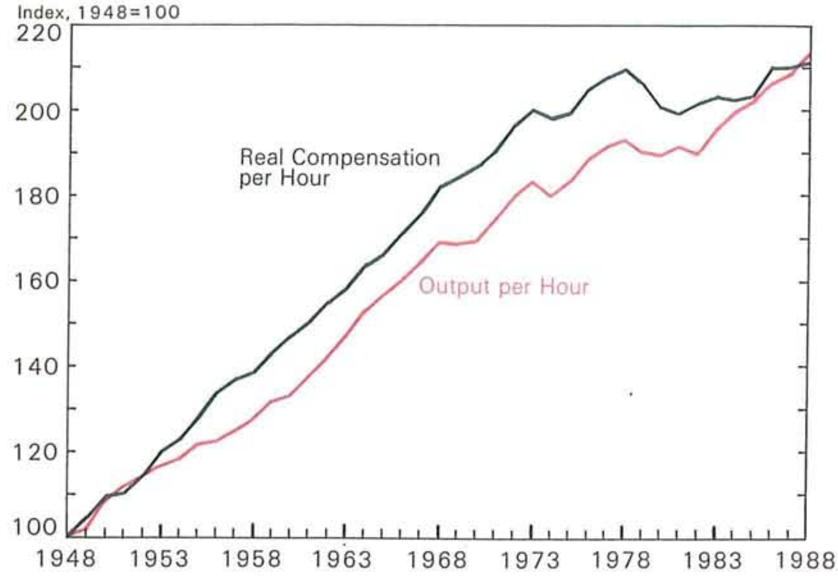
One final rearrangement of equation (2) reveals the relationship between multifactor productivity and the traditional measure of output per hour. Subtracting the growth rate of labor from both sides of the equation combined with some algebraic manipulation yields the following relationship:[4]

(4) % Q growth − % L growth = % MFP growth + s_k(% K growth − % L growth).

This shows that the difference in the rate of growth of output and labor input, or, in other words, the growth of labor productivity, is equal to the sum of multifactor productivity growth plus the rate of change in the capital labor ratio multiplied by capital's share in total output. This latter component reflects the contribution to output growth resulting from the increased amount of capital per person. Hence, the two concepts—labor productivity and multifactor productivity—are closely related.

Chart 1

Output per Hour and Real Compensation per Hour in the Private Nonfarm Business Sector, 1948-88



Source: U.S. Bureau of Labor Statistics, unpublished data.

higher standards of living but also because it mediates social conflict. When the ratio of output to input rises, it is possible for some people to consume more without others consuming less. An environment of rising living standards makes the more affluent members of society more willing to share with those less fortunate. If the pie is not growing, people try to preserve what they have and show less concern for the poorer members of society.

Rapid productivity growth also makes it easier to trade off the production of goods and services for other products that contribute to social welfare. Using labor and capital to abate pollution or to improve worker health and safety necessarily reduces measured productivity; the factor inputs show in the denominator, but no additional output appears in the numerator. The more efficiently factors of production are used to produce conventionally measured goods and services, the more easily some of them can be diverted to satisfy social objectives.

Given the profound implications of productivity growth for standards of living, the distribution of income, and the welfare of individuals and the environment, it is extremely important to figure out what has happened to productivity growth and what can be expected in the future.

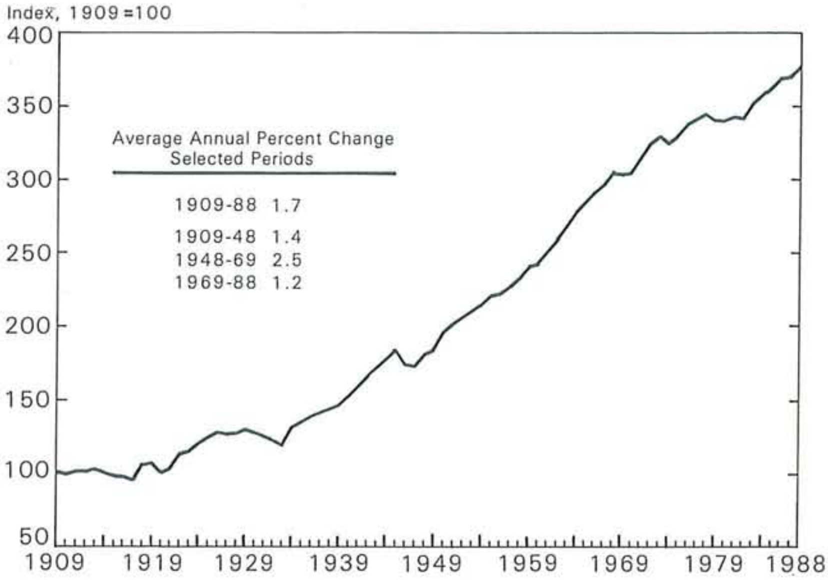
II. How Has Productivity Fared over Time?

Indexes of labor productivity and multifactor productivity for broad economic sectors and for manufacturing are published by the Bureau of Labor Statistics. Measures of output per hour have been developed for the business sector, and for the farm and nonfarm subsectors, from 1909 to the present. For the period after 1947, these data have been supplemented with comparable measures for manufacturing (total, durable and nondurable) and nonfinancial corporations. Multifactor productivity data are available for private business, private nonfarm business, and manufacturing from 1948 to the present.[5]

The following discussion will focus on the productivity data for the private nonfarm business sector. These series avoid the distorting effects created by the movement from farming to industry, and therefore offer some limited standardization. Except for a cursory mention of overall trends, separate data will not be presented for manufacturing. Denison (1989) has made a convincing argument that the present methodology, and particularly the treatment of computers, ends up attributing too much of recent growth to the manufacturing sector. Young (1989), of

Chart 2

Output per Hour in the Private Nonfarm Sector, 1909-88



Source: U.S. Bureau of Labor Statistics, unpublished data.

the Bureau of Economic Analysis, counters that Denison's study does not present convincing reasons to change the treatment of computers. Since this question is still unsettled, the paper will focus on the private nonfarm business sector.

Chart 2 shows the level of labor productivity in the private nonfarm economy over the period 1909 (the first year of official productivity measures) through 1988. In general, productivity has moved upward; a person working in 1988 could produce nearly four times more output in an hour than a person in 1909.

The strength of U.S. labor productivity is also demonstrated by international comparisons. Chart 3 shows gross domestic product per employed person for the United States and six developed countries. Although the gap between the United States and the other countries has narrowed significantly since the 1960s, the United States still has the highest level of gross domestic product per worker. Canada came closest to the United States in 1988, but its real product per civilian employee still remained 5 percent below the United States.

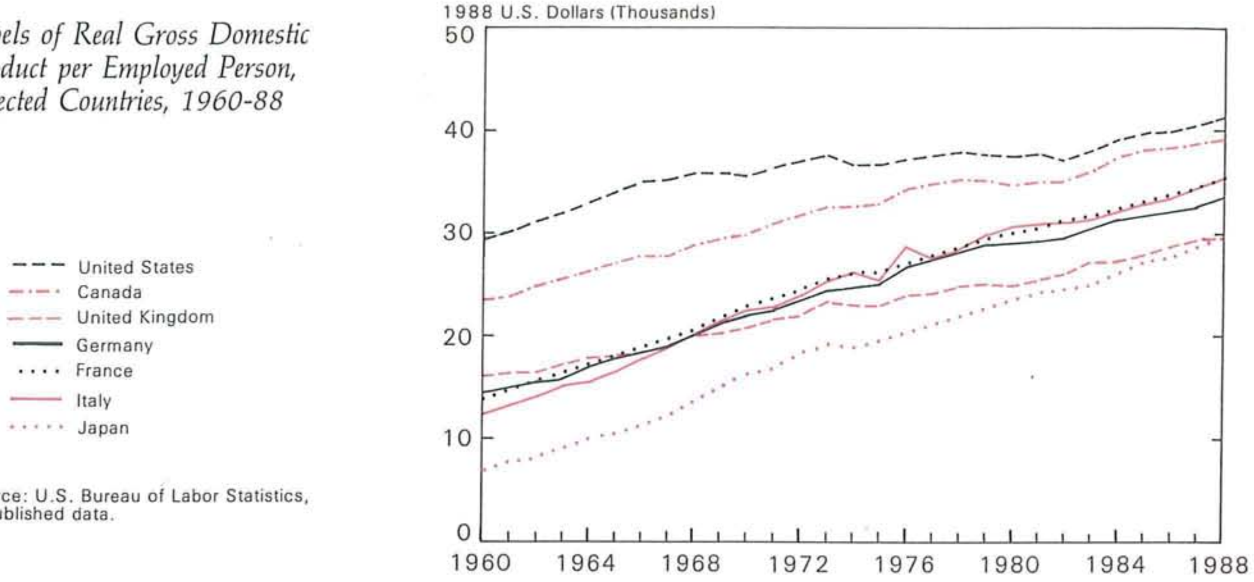
The problem in the United States is therefore not one concerning the level of productivity (output per worker is higher in the United States than in any other major developed nation) or the direction of change (except for the 1930s output per worker has increased almost every year), but rather the rate at which output per unit of labor input increases. As the previous section made clear, the rate of productivity increase determines the rate of growth of real wages and living standards. The type of international comparison that tends to cause so much alarm in the United States is presented in chart 4. The data show that since 1960 the rate of increase in real gross domestic product has been substantially greater in other major industrialized countries than in the United States. As noted frequently in the popular press, output per worker in Japan has increased more than fourfold over the last three decades, while in the United States it has gone up by less than 50 percent.

If the unfavorable comparisons were limited only to the international scene, it would be possible to explain the discrepancies largely in terms of other countries recovering from the devastation of World War II and catching up to U.S. levels. The problem is that U.S. productivity growth in the 1970s also fell sharply from its own previous heights.

Before looking at the data, one word is required

Chart 3

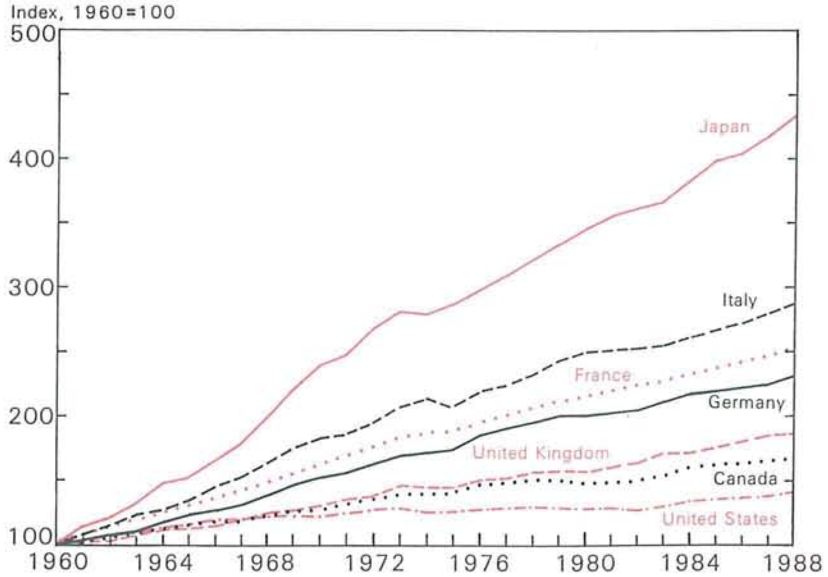
Levels of Real Gross Domestic Product per Employed Person, Selected Countries, 1960-88



Source: U.S. Bureau of Labor Statistics, unpublished data.

Chart 4

Trends in Real Gross Domestic Product per Employed Person, Selected Countries, 1960-88



Source: U.S. Bureau of Labor Statistics, unpublished data.

Table 1
Average Annual Percentage Change in Output, Factor Inputs, and Productivity Ratios for the Private Nonfarm Business Sector, Selected Periods, 1948–87

		Labor Measures		Contribution of Capital			Multifactor Measures	
Period	Output	Labor Input	Labor Productivity	Capital-Labor Ratio	Capital's Share	Capital's Contribution to Output per Hour	Capital-Labor Input	Multifactor Productivity
1948–87	3.3	1.4	1.9	2.1	35.2	.7	2.2	1.1
1948–69	3.8	1.2	2.5	2.1	35.6	.7	2.0	1.8
1969–87	2.8	1.6	1.1	2.1	34.8	.7	2.4	.4
1948–60	3.3	.8	2.5	2.1	35.2	.7	1.5	1.7
1960–69	4.5	1.9	2.6	2.1	35.9	.7	2.6	1.8
1969–79	2.9	1.8	1.1	2.1	34.7	.7	2.5	.4
1979–87	2.7	1.4	1.2	2.2	34.8	.8	2.2	.4
1948–53	4.6	1.4	3.2	1.9	35.6	.7	2.0	2.5
1953–60	2.4	.4	2.0	2.3	34.9	.8	1.2	1.2
1960–69	4.5	1.9	2.6	2.1	35.9	.7	2.6	1.8
1969–73	3.6	1.5	2.0	2.7	34.5	.9	2.4	1.1
1973–79	2.5	2.1	.5	1.7	34.7	.6	2.6	−.1
1979–87	2.7	1.4	1.2	2.2	34.8	.8	2.2	.4

Source: U.S. Bureau of Labor Statistics, Major Sector Labor and Multifactor Productivity, machine readable data, and unpublished data.

about the cyclical aspect of productivity performance. Strong aggregate demand always gives a temporary boost to productivity as workers are employed more intensively and capital is used for extra hours. A recession, on the other hand, always causes a temporary dip in productivity; not all firms have enough work and some assign employees to maintenance tasks rather than production. Two approaches have been used to eliminate this relationship between the business cycle and productivity in order to reveal the underlying trends. The first is to cyclically adjust the data by estimating the extent to which short-run fluctuations in demand lead to short-run variations in output and productivity and then remove these effects from the data. The alternative is to simply calculate productivity trend growth rates from high-employment year to high-employment year to avoid the large cyclical variations in productivity. The latter approach has been adopted here, since altering the published data makes it virtually impossible to refer back to the original sources.

Table 1 presents information about the rate of growth of total output, factor inputs and productivity in the private nonfarm business sector for various periods and subperiods from 1948 through 1987. Let us start with the simplest concept—labor productivity—and the longest time period. Over the entire four decades, total nonfarm business output increased at an annual average rate of 3.3 percent, and labor input to that sector measured in hours grew 1.4 percent, so labor productivity growth (the difference between the rates of growth of output and labor input) averaged 1.9 percent.

Breaking the post–World War II period in half shows that the overall average consists of high economic growth, 3.8 percent annually, and rapid labor productivity increases, 2.5 percent per year, before 1969 and slower growth in both output, 2.8 percent, and labor productivity, 1.1 percent, thereafter. Part of the decline in labor productivity growth may be attributable to the relationship between productivity and economic activity, but the size of the drop after 1969 is much greater than can be explained by the retardation in the growth of real output. Based on the relationship between labor productivity growth and the growth in nonfarm business output over the period 1948–69, one would predict labor productivity growth of 1.8 percent for 1969–87.

The question is what happened to cause the slowdown in the growth of labor productivity after 1969. Labor productivity consists of two components: (1) the increase in multifactor productivity or improved management of resources and technical progress and (2) the contribution from the increase in the capital-labor ratio. Table 1 shows that the rates of growth in the capital-labor ratio were identical over the pre- and post-1969 periods: 2.1 percent annually.

The size of the drop in labor productivity growth after 1969 is much greater than can be explained by the retardation in the growth of real output.

Capital's share in total output, which is the weight used to determine its contribution to the growth in output per hour, remained virtually unchanged over the two periods. As a result, capital's contribution was the same before and after 1969. This means that the slowdown in labor productivity growth since 1969 appears to be due solely to a decline in multifactor productivity growth.

As discussed earlier, multifactor productivity can be thought of as similar to labor productivity except that the factor input is a weighted average of labor and capital. Subtracting the average annual growth in this combined factor input of 2.2 percent from the 3.3 percent growth in output yields an annual average growth in multifactor productivity over the 1948–87 period of 1.1 percent. This average, however, is the result of 1.8 percent annual growth in multifactor productivity before 1969 and 0.4 percent after 1969.

A finer breakdown of years yields a little more information, but not much. Specifically, the years 1973 through 1979, which have been the focus of considerable attention, show the lowest gain in labor productivity, and even a decline in multifactor productivity. Moreover, during this period the contribution of capital to output per hour also dropped to its lowest level in the postwar period. This is the result of the abrupt decline in the rate of growth in the capital-labor ratio that accompanied the influx of the baby boom into the labor market.

The basic fact is that before 1969 the United States experienced high productivity growth and now productivity growth is considerably lower. The questions that need to be answered are: Why did this drop occur? and What will happen in the future?

III. Explaining the Slowdown

This is not the first attempt to explain the slowdown in productivity growth; in fact, accounting for the slowdown has become a major industry among economists.[6] While an enormous number of popular hypotheses have been developed, none appear to explain more than a fraction of the overall decline. The following section first explores those hypotheses directly related to capital or labor, and then turns briefly to a series of other possible contributors to the slowdown.

Changes in the Composition of the Labor Force

One of the oldest, most popular hypotheses, and one that will be reexamined here, is that the skill and experience of the labor force have deteriorated significantly. The simple productivity calculations prepared by the Bureau of Labor Statistics use worker hours as the measure of labor input. This procedure gives the same weight to each hour worked, even though people differ greatly in their abilities and experience. Thus, economists have attempted to make adjustments for the quality of labor input by taking into account both changing demographic characteristics and level of education.

Demographic changes. The structure of the labor force changed dramatically as the baby boom generation moved through during the 1970s; adult males were 55 percent of employed persons in 1970 but only 47 percent in 1979. The productivity calculations assume that an hour of work by an adult male is just as useful as an hour supplied by an inexperienced teenager. But the wage rates of adult males are three times as great as those of teenagers and one and one-half times those of women (Denison 1985, Table 3-5). Economic theory suggests that the differences in wages reflect differences in productivity; if this were not true, the argument goes, employers would fire their more expensive older workers and hire less expensive younger ones.

This is a somewhat delicate argument; most observers stand ready to accept the idea that teenagers have lower productivities, but many (if not all) cannot accept the notion that women are inherently less productive than men. The wage differentials, in fact, probably have nothing to do with the inherent abilities of different groups, but most likely reflect differences in work experience.

To capture the variation in work experience resulting from the changes in the age-sex mix of the labor force, several economists have constructed a quality-adjusted labor force variable in which workers in each demographic group are weighted by the wage for that group (Perry 1971, Baily 1981, Denison 1974, 1979 and 1985, and Darby 1984). We have updated those estimates and found results consistent with the earlier efforts. The exercise involves multiplying the annual share of total hours worked by each age-sex group (males and females aged 14–19, 20–24, 25–34, 35–64, 65 and over) by a wage weight.[7] The wage weight, which was taken from Denison (1985, Table 3-5), is the ratio of the average earnings for each age-sex group to the average earnings of males aged 35 to 64. These weighted hours are then summed over all groups. This annual adjustment is then applied to the index of hours from the Bureau of Labor Statistics to derive an age-sex adjusted index of labor input.

The results show that effective labor input grew more slowly than reported hours over the whole postwar period and that the discrepancy widened after 1969 (table 2). However, of the 1.4 percentage point decline in labor productivity from the first half of the period to the second, the changing age-sex mix of the labor force appears to explain only 0.2 percentage points. This is similar to the results found by earlier authors.

Table 2
Average Annual Percentage Change in Actual and Quality-Adjusted Labor Input and Labor Productivity, Selected Periods, 1948–87

	Labor Input		Labor Productivity	
Period	Actual (BLS)	Quality-Adjusted	Actual (BLS)	Quality-Adjusted
1948–87	1.4	1.2	1.9	2.1
1948–69	1.2	1.1	2.5	2.7
1969–87	1.6	1.3	1.1	1.5
1948–60	.8	.7	2.5	2.5
1960–69	1.9	1.5	2.6	2.9
1969–79	1.8	1.2	1.1	1.8
1979–87	1.4	1.4	1.2	1.2
1948–53	1.4	1.5	3.2	3.1
1953–60	.4	.2	2.0	2.1
1960–69	1.9	1.5	2.6	2.9
1969–73	1.5	.5	2.0	3.0
1973–79	2.1	1.6	.5	.9
1979–87	1.4	1.4	1.2	1.2

Source: U.S. Bureau of Labor Statistics and author's estimates.

Education. One could argue that the logic that justifies wage-weighting of labor input requires adjusting also for trends in educational attainment over time. How to measure educational achievement and the effect of additional education on productivity, however, are both tricky issues.

Effective labor input grew more slowly than reported hours over the whole period, with the discrepancy widening after 1969.

Darby (1981) uses median years of school as an index of education. This number remained at slightly over 8 years until the end of World War II, rose rapidly to 12 years in 1970, and then more or less leveled off, reaching 12.5 years in 1980. Hence, at first glance, a slowdown in educational achievement would appear to explain a portion of the slowdown in productivity. The median, however, simply shows that one-half of the population has at least 12 years of education and one-half has less, which is not surprising since a significant fraction of the population completes only high school. Other measures of educational attainment continued to rise throughout the 1970s; the percentage of the population that completed high school increased from 52 percent in 1970 to 66 percent in 1980, and the percent completing four years of college rose from 11 percent to 16 percent over the same ten-year period.

Other economists (Fraumeni and Jorgenson 1981, and Denison 1985) have made much more elaborate efforts to estimate the educational human capital in the labor force. They both used estimates of the extent to which an additional year of education adds to a worker's income, which puts a productivity value on a year of schooling. They also provided detailed information on the distribution of educational attainment in the work force. Both found that the U.S. work force was becoming more and more educated.

The conclusion that increased education leads to improvements in productivity, however, assumes that the quality of education has remained constant over the period. Some data indicate that educational quality may have diminished over time. Scholastic Aptitude Test

(SAT) scores have been declining since the mid 1960s after showing a slight upward trend for some years. In 1967, students averaged 466 on the verbal part of the test and 492 on the mathematical part; by 1980, these scores had declined to 424 and 466 respectively (U.S. Bureau of the Census 1989, Table 237). This trend is consistent with other studies that have shown that the rate of return to education has been falling (Freeman 1976, and Smith and Welch 1978). Baily (1981) concludes that "In contrast to improvements in education in earlier years, it seems unlikely that the further increases in recent years have been important."

In short, the major factor affecting the quality of the labor force is probably the influx of inexperienced workers that occurred in the 1970s as the baby boom was absorbed and the ranks were swelled by newly entering female workers. Weighting the age-sex groups by their relative wages is an imperfect adjustment for capturing experience differences, but the exercise does indicate that the changing mix has been responsible for part of the slowdown.

The Growth in Capital and Its Services

The other factor of production is capital, so that both a slowdown in the accumulation of capital and a slowdown in the services provided by a given stock of capital are potential causes of the slowdown. Hudson and Jorgenson (1974) in an early article suggested that the rate of capital investment may have slowed in response to the increase in energy prices. Their argument rests on the notion that automation is a major motivation for investment, and the incentive to pursue this process, which involves replacing human power with machine and energy power, is greatly reduced when the cost of energy rises. The difficulty is that the 1970s did not turn out to be a period of low investment; rather, the rate of growth in capital input remained at its post–World War II average level. Historical rates of growth, however, were inadequate to maintain capital-labor ratios in the face of the huge influx of new workers. The decline in the capital-labor ratio surely contributed to the decline in labor productivity.

The decline in the capital-labor ratio in the 1970s surely contributed to the decline in labor productivity.

When estimating productivity, the relevant input is not really the stock of capital but rather the flow of capital services. Baily (1981) argued that, even though capital formation remained quite strong, the flow of capital services may have deteriorated significantly and this deterioration may account for a significant portion of the productivity slowdown. The decline in capital services could be due to any of three factors. First, the rise in energy costs made some of the existing energy-inefficient capital obsolete. Second, pollution abatement and worker safety regulations diverted part of the flow of new investment to assets that do not help to increase output. Third, the maturing of some industrializing countries and the strong dollar made many U.S. factories uncompetitive. As a result of these developments, some capital was scrapped prematurely and, most importantly, some was never used. Although the evidence for this hypothesis is mixed, capital was probably not used as efficiently in the 1970s as in the past.

Other Explanations for the Slowdown

Some other often-cited contributors to the productivity slowdown are the increase in energy prices, the falloff in research and development expenditures, the diversion of investment funds to pollution abatement and worker health and safety improvements, and the mismeasurement of output.

The run-up in oil prices in the early 1970s is a convenient explanation because it coincided with the slowdown in productivity. The evidence in this area is mixed, with economists on both sides equally convinced of the importance or unimportance of energy prices as a contributor. Jorgenson (1988) argues that aggregate productivity slowdown is a result of slowdowns in individual industries that can be traced back to the rise in energy prices. Since the model of aggregate production excludes energy input, any negative effect of energy prices on output will be reflected in a slowdown of productivity. As noted earlier, Baily (1981) and Griliches (1988) argue that energy price changes forced companies to scrap energy-inefficient capital prematurely, or use it less intensively, and thus had a significant impact on productivity.

On the other side of this argument, Berndt (1980) concludes that energy price variations have not significantly affected labor productivity growth primarily because energy costs are such a small portion of total costs. Denison (1985) points out that price increases occurred after productivity declines and were probably responsible for at most 0.1 percentage point of the decline. Thus, while energy's contribution to the slowdown is still a debated topic, it cannot be cited as a major contributor.

Another factor often cited as a reason for the slowdown is the levelling off in the rate of growth of research and development (R&D) expenditures. Griliches (1988), a pioneer in this area, concludes, however, that the R&D slowdown did not play a major role. Dean and Kunze (1988) and Baily and Chakrabarti (1988) also find similar results. One dissenting voice in this argument is Kendrick (1979), who attributes a substantial portion of the decline to the falloff in R&D expenditures. He finds such a large impact because he assumes not only that R&D expenditures levelled off, but also that the return on these expenditures has declined over time. The second assertion is a point of contention among economists. Thus, the preponderance of evidence indicates that although the decrease in R&D expenditures may have been of some importance, this phenomenon was not a major contributor to the productivity slowdown.

The diversion of investment expenditures to pollution abatement and worker health and safety improvement (in order to comply with federal regulation) has also been advanced as a potential cause. As discussed earlier, these types of investments are counted as part of the capital stock, and therefore as inputs, but do not produce any measured output. As with the levelling off in R&D expenditures, most studies (Crandall 1980; Denison 1985; Norsworthy, Harper, and Kunze 1979) have found that little of the slowdown can be attributed to efforts to meet increasing regulatory requirements. Gray (1984) estimated an effect on productivity about twice as large as that found by those using growth accounting. Again, the majority of findings indicate that the diversion of investment funds, while able to explain a small portion of the productivity decline, cannot be viewed as a major cause.

The last explanation that has been used to shed some light on productivity declines is the potential mismeasurement of output. Baily and Gordon (1988) found serious problems with the measurement of both output and productivity. They argue that the price indices used to deflate nominal output are highly inaccurate for some industries, especially those in the services sector, a problem which has been cited by other economists. Paradoxically, they conclude that these problems do not explain a large portion of the slowdown (0.2 percentage points of a 1.4 point decline) because although real output was understated in the 1970s, it was also understated in prior years. They do believe, however, that measurement errors may have been worsening since 1973. Their assessment requires further investigation and digestion by economists before measurement error can fully be accepted as an important contributor to the productivity slowdown.

Evidence indicates that such factors as rising energy costs, reduced R&D spending, diversion of funds to pollution abatement, and mismeasurement of output explain only a small part of the slowdown in productivity.

This brief excursion highlights the causes most often cited in the productivity slowdown puzzle and the piecemeal nature of the explanations. While several of these effects would seem intuitively to be important explanatory factors, the empirical evidence shows that most of them explain only a bit of the slowdown, and none can be considered a major contributor.

IV. The Role of Public Capital in Explaining the Slowdown

An additional explanatory factor that has not yet been thoroughly investigated is public capital. Until the recent study by Aschauer, this component of the nation's capital stock had been virtually ignored in the analyses of productivity growth. This oversight is difficult to explain, since the stock of public capital is not small. As shown in table 3, in 1987 public capital amounted to more than $2.3 trillion compared to slightly more than $4 trillion in the private sector. Even ignoring investments devoted to military purposes, the stock of public capital amounted to almost $1.9 trillion, or 45 percent of the value of the stock of private capital.

Table 3
Private and Public Capital Stock, 1987

Capital Stock[a]	Billions of Dollars	Percent of Total
Total	6487.3	
Total Private	4142.8	64
Nonfarm business	3974.6	61
Farm	168.2	3
Total Public	2344.5	36
Military	457.7	7
Nonmilitary	1886.8	29
Core infrastructure[b]	1195.7	18
Education, hospital and other buildings[c]	535.9	8
Conservation and development	155.2	2

Note: Numbers may not add to totals due to rounding.
[a]Figures include equipment and structures only. Land, inventories, and rental residential capital are excluded.
[b]Includes highways, mass transit, airports, electrical and gas facilities, water supply facilities, and sewers.
[c]Other buildings include office buildings, police and fire stations, courthouses, garages, and passenger terminals.
Source: U.S. Bureau of Economic Analysis, unpublished data.

Nearly two-thirds of nonmilitary public capital consists of "core infrastructure," which includes not only the highways, airports, and mass transit facilities that link this nation together, but also electric and gas plants, water supply facilities, and sewers that allow industry to operate. The second major category of nonmilitary public capital is buildings, including schools, hospitals, police and fire stations, courthouses, garages and passenger terminals, all of which contribute to an orderly environment that facilitates private production. The final category, which is relatively small, consists of structures used in conservation and development.

The importance of public capital to the private production process should be obvious. The construction of a highway allows a truck driver to avoid circuitous back roads and bring goods to market in much less time. The reduction in required time means that the producer pays the driver lower wages and the truck experiences less wear and tear. Hence, public investment in a highway enables private companies to produce their products at lower total cost. The condition of the highway, however, can be just as important as its existence. A highway in poor condition reduces the productivity of both private capital and labor; the wear and tear on trucks increases and the driver takes longer to make the trip, requiring greater compensation. Although less direct, similar stories can be told for police and fire stations, garages, mass transit and other components of public capital.

Not only does public nonmilitary capital consist of inputs essential to private sector output, but the growth of public capital has varied significantly over time and in a fashion consistent with the pattern of productivity growth. That is, as shown in table 4, the stock of public capital grew rapidly in the immediate postwar period when productivity growth was strong, and then increased at a much slower pace in the 1970s and 1980s when productivity growth lagged. This pattern is even more pronounced for public nonmilitary capital, which grew at an annual average rate of 4.1 percent over the period 1948–69 compared to 1.6 percent for 1969–87. Table 5 provides some additional information on growth rates by level of government.

A strong relationship between output per unit of private capital and the stock of public capital has been identified by Aschauer (1989). He also found a statistically significant relationship between the level of multifactor productivity and the stock of nonmilitary capital. This section will take Aschauer's analysis a step further by recalculating multifactor productivity from a production function that includes public as well as private capital. The object of this exercise is to see whether the slump in multifactor productivity growth in the last two decades persists after taking account of the slowdown in public investment.

Not only does public nonmilitary capital consist of inputs essential to private sector output, but the growth of public capital has varied consistently with the pattern of productivity growth.

As discussed earlier, multifactor productivity growth is the residual left after subtracting from the growth in total output (Q) the direct contributions from increased amounts of capital (K) and labor (L). These increased contributions are calculated as the

Table 4
Average Annual Percentage Change in the Real Value of Private and Public Capital Stock, Selected Periods, 1948–87

Period	Private Nonfarm Business	Public				
				Nonmilitary		
		Total	Military	Total	Core Infrastructure	Other
1948–87	3.7	2.4	.9	3.0	2.8	3.3
1948–69	4.0	3.0	−.1	4.1	3.7	5.0
1969–87	3.3	1.7	2.1	1.6	1.7	1.4
1948–60	3.7	2.4	−.5	3.7	3.3	4.5
1960–69	4.4	3.7	.4	4.7	4.2	5.5
1969–79	3.6	1.7	.1	2.1	2.0	2.3
1979–87	3.0	1.6	4.8	1.0	1.3	.3
1948–53	3.9	1.4	−2.2	3.2	2.7	4.4
1953–60	3.6	3.1	.7	4.1	3.8	4.6
1960–69	4.4	3.7	.4	4.7	4.2	5.5
1969–73	4.0	2.1	−.9	2.8	2.6	3.1
1973–79	3.3	1.5	.7	1.6	1.6	1.8
1979–87	3.0	1.6	4.8	1.0	1.3	.3

Source: U.S. Bureau of Economic Analysis, 1987, *Fixed Reproducible Tangible Wealth in the United States, 1925–85*, and unpublished data.

growth in factor inputs multiplied by their effect on output. This effect or elasticity is the percentage change in output for a given change in the relevant input. It is generally assumed that factor markets are perfectly competitive, so factors are paid their marginal product, and that the production function exhibits constant returns to scale, so that a 10 percent increase in private capital and labor leads to a 10 percent increase in output, which means that the elasticities applied to the growth of capital and labor are equal to their relative shares of total income. Since these shares have been very stable over time, the traditional equation for multifactor productivity growth (MFP) looks as follows:

$$\% \text{ MFP growth} = \% \text{ Q growth} - .35 (\% \text{ K growth}) - .65 (\% \text{ L growth}).$$

Introducing the average growth rates for total output, capital, and labor over the period 1949–87,

$$\% \text{ MFP growth} = 3.3 - .35(3.6) - .65(1.4),$$

and the average annual increase in multifactor productivity can be shown to equal 1.1 percent.

To take account of nonmilitary public capital (G) in the multifactor productivity calculation involves

Table 5
Average Annual Percent Change in the Real Public Nonmilitary Capital Stock, Selected Periods, 1948–87

Period	Total	Federal	State & Local
1948–87	3.0	1.4	3.3
1948–69	4.1	2.0	4.7
1969–87	1.6	.8	1.7
1948–60	3.7	1.9	4.3
1960–69	4.7	2.1	5.3
1969–79	2.1	.5	2.4
1979–87	1.0	1.1	.9
1948–53	3.2	3.1	3.3
1953–60	4.1	1.1	5.0
1960–69	4.7	2.1	5.3
1969–73	2.8	0	3.3
1973–79	1.6	.8	1.8
1979–87	1.0	1.1	.9
Addendum: 1987 Amounts (billions)	$1,887	$264	$1,623

Source: U.S. Bureau of Economic Analysis, 1987, *Fixed Reproducible Tangible Wealth in the United States, 1925–85*, and unpublished data.

subtracting an additional term reflecting the growth in public capital times its impact on output. In other words, the equation becomes

$$\% \text{ MFP growth} = \% \text{ Q growth} - a(\% \text{ K growth}) - b(\% \text{ L growth}) - c(\% \text{ G growth}).$$

The issues to be resolved are the values for a, b and c and whether or not the three coefficients sum to one. That is, does the assumption of constant returns to scale hold once public capital is included?

The basic rationale for government provision of goods and services is that these commodities will not be produced by the private market. The classic case is a good or service whose benefits may be provided to everyone in a town or a nation at a cost no greater than that required to provide it to one person (national defense). The benefits of the good cannot be divided up and people cannot be excluded from using it. The inability to exclude those unwilling to pay means that a profit-making producer would have no incentive to supply such items.

Sometimes government provision is called for even if exclusion is possible, as in the case of bridges or the interstate highway system. The reason is that these types of infrastructure can produce services with enormous economies of scale; although the initial fixed cost might be quite large, the marginal cost of providing one more crossing or road trip is nearly zero. Therefore, while it would be feasible to exclude those unwilling to pay from using the project, such exclusion would be inefficient.

The basic rationale for government provision of goods and services is that these commodities will not be produced by the private market.

Given that economies of scale play such a key role in determining the public provision of a good or service, one might be tempted to conclude that public capital in total may yield economies of scale within the production function. Such a leap may not be warranted, however. While a given highway may yield economies of scale, the construction of additional highways within the national production function may not. For example, the first phase of highway construction in the late 1940s and 1950s probably had an enormous impact on aggregate output, most likely in the realm of increasing returns to scale. As more roads were built, however, the increase in output as a result of the new construction may well have declined, so that the relationship would be more accurately described in terms of constant returns. In the same vein, a doubling of the highway system would probably produce diminishing returns.

Because of the uncertainty about the impact of public capital on output, Aschauer estimates two forms of a capital productivity equation: one that assumes that the production function exhibits constant returns to scale over private inputs and increasing returns to scale overall, and one that assumes constant returns to scale across all factors, public and private. The estimated equations, however, provide no basis for distinguishing between the two assumptions.

In an effort to get a more precise answer to the question of returns to scale and also to confirm Aschauer's results, which, if robust, have wide-ranging implications, we updated and reestimated in a slightly different form some of the productivity equations. Regardless of the precise form of the estimated equation, the process begins by rewriting the production function to include public capital. The easiest way to conceptualize how public capital fits into the production function is to view the flow of government services as enhancing the output from both labor and private capital. Hence, public capital becomes another input in the production function and the equation looks as follows:

$$Q = (MFP)*f(K,L,G).$$

Assuming a generalized Cobb-Douglas form of technology yields a more specific relationship between inputs and outputs:

$$Q = MFP*K^aL^bG^c.$$

Translating this equation into logarithms produces a linear function that can be estimated:

$$\ln Q = \ln MFP + a\ln K + b\ln L + c\ln G.$$

Instead of subtracting the log of capital from each side as Aschauer did, we subtract labor in order to have the more familiar labor productivity measure on the left-hand side. Hence, the first equation to be estimated is

$$\ln Q - \ln L = \ln MFP + a\ln K + (b - 1)\ln L + c\ln G.$$

Table 6
Regression Results: Labor Productivity, Private and Public Capital, Annual Data 1949–1987

Equation for Output Per Hour (lnQ − lnL)							rho	$\bar{R}^2$	SE	DW
			Private Capital Only							
(1) No Constraint:	lnA +	alnK +	(b−1)lnL +	dCU						
	5.84	.62	−.96	.62			.96	.998	.0101	1.88
	(5.4)	(2.6)	(4.6)	(5.8)			(28.6)			
(2) a + b = 1:	lnA +	a(lnK − lnL) +		dCU						
	4.28	.55		.41			.93	.997	.0112	1.77
	(33.4)	(3.2)		(4.4)			(25.7)			
			Including Total Nonmilitary Public Capital							
(3) No Constraint:	lnA +	alnK +	(b−1)lnL +	clnG +	dCU					
	4.45	.64	−1.02	.31	.66		.74	.998	.0099	1.68
	(7.3)	(4.1)	(4.4)	(3.2)	(5.8)		(4.7)			
(4) a + b = 1:	lnA +	a(lnK − lnL) +		clnG +	dCU					
	2.73	.26		.37	.18		.99	.995	.0144	1.39
	(.9)	(.9)		(1.9)	(1.3)		(9.2)			
(5) a + b + c = 1:	lnA +	a(lnK − lnL) +		c(lnG − lnL) +		dCU				
	4.12	.56		.33		.60	.73	.998	.0097	1.67
	(103.9)	(12.6)		(5.0)		(11.8)	(5.5)			
(6) a = c:	lnA +	a(lnK + lnG) +		(b−1)lnL	+dCU					
	3.57	.41		−.67	.49		.71	.998	.0101	1.56
	(14.4)	(14.1)		(5.8)	(6.7)		(5.9)			
(7) a = c and a + b + c = 1:	lnA +	a(lnK + lnG − 2lnL)			+ dCU					
	4.30	.34			.49		.96	.998	.0103	1.73
	(27.9)	(4.1)			(5.5)		(30.6)			

Note: t-statistics in parentheses; Q = index of private nonfarm business output; A = the level of technology; K = index of private nonfarm business capital services; L = index of labor input in the private nonfarm business sector; G = index of the stock of nonmilitary public capital; and CU = capacity utilization rate in manufacturing.

To test for economies of scale, two additional equations are also estimated. The first assumes that constant returns to scale hold only for the private inputs, but that the entire production function shows increasing returns to scale. This assumption is captured by setting a + b = 1, so that the equation looks as follows:

$$\ln Q - \ln L = \ln MFP + a(\ln K - \ln L) + c\ln G.$$

The alternative assumption is that constant returns to scale applies to the entire production function, so that a + b + c = 1. Imposing this second constraint produces the third equation:

$$\ln Q - \ln L = \ln MFP + a(\ln K - \ln L) + c(\ln G - \ln L).$$

Three sets of equations were estimated—one with private capital only, one introducing total nonmilitary capital, and one including only the core infrastructure portion of public capital. The output, hours, and private capital data are the same as those used by the BLS to calculate multifactor productivity. Labor is measured as hours worked and private capital is introduced as the services flowing from the private capital stock.[8] The question was whether to construct a service series for the public capital stock as well; we followed Aschauer and simply assumed that services were proportional to the stock in the public sector. The equations also include the level of capacity utilization in manufacturing in order to reflect the cyclical nature of productivity.

The regression results, which are summarized in tables 6 and 7, confirm Aschauer's finding that public capital does indeed belong in the production function.[9] Both total nonmilitary public capital and core infrastructure enter with coefficients similar to

Table 7
Regression Results: Labor Productivity, Private Capital and Core Infrastructure, Annual Data 1949–87

Equation for Output Per Hour (lnQ − lnL)						rho	$\bar{R}^2$	SE	DW
Including Only Core Infrastructure									
(1) No Constraint:	lnA	+ alnK	+ (b−1)lnL	+clnGC	+ dCU				
	4.37	.62	−1.06	.37	.68	.67	.998	.0096	1.68
	(6.9)	(4.0)	(4.5)	(3.9)	(6.1)	(3.9)			
(2) a + b = 1:	lnA	+ a(lnK − lnL)		+ clnGC	+ dCU				
	3.32	.44		.21	.37	.85	.997	.0113	1.73
	(3.2)	(2.3)		(.9)	(4.1)	(6.1)			
(3) a + b + c = 1:	lnA	+ a(lnK − lnL)		+ c(lnGC − lnL)	+ dCU				
	4.09	.56		.39	.63	.65	.998	.0094	1.67
	(104.2)	(16.2)		(7.2)	(12.7)	(4.6)			
(4) a = c:	lnA	+ a(lnK + lnG)	+ (b−1)lnL		+ dCU				
	3.65	.45	−.78		.55	.61	.998	.0096	1.60
	(17.3)	(17.70)	(7.78)		(8.1)	(4.9)			
(5) a = c and a + b + c = 1:	lnA	+ a(lnK + lnG − 2lnL)			+ dCU				
	4.09	.49			.63	.69	.998	.0100	1.43
	(109.0)	(34.7)			(13.7)	(5.5)			

Note: t-statistics in parentheses; Q = index of private nonfarm business output; A = the level of technology; K = index of private nonfarm business capital services; L = index of labor input in the private nonfarm business sector; GC = index of the stock of public nonmilitary core infrastructure; and CU = capacity utilization rate in manufacturing.

those found by Aschauer and are generally statistically significant. The coefficients of 0.31 to 0.39 imply that a 1 percent increase in public capital would raise labor productivity by 0.31 to 0.39 percent.

The equations also seem to provide some information about returns to scale; the equation based on the assumption a + b + c = 1 has a somewhat smaller standard error than the unconstrained equation and a noticeably smaller error than the equation based on the assumption that constant returns apply only to the private factors of production. Hence, the answer to the question regarding the values of a, b and c appears to be that c = 0.33 and a + b + c = 1.

The difficulty, however, is that the coefficient for private capital of 0.56 in equation (5) of table 6 is much larger than one would have thought based on factor shares, and this implies a very low elasticity of output with respect to labor; with constant returns to scale, if a = 0.56 and c = 0.33, then b = 0.11. These figures are difficult to reconcile with the relationship between a and b embodied in the traditional assumption of a = 0.35 and b = 0.65, which are the shares of total income going to private capital and labor, respectively.

One explanation for the counterintuitive coefficient for capital is that a variable has been omitted from the equation, and indeed the size and significance of the first order serial correlation coefficient indicate that a systematic pattern exists that has not been identified. The introduction of a trend and some additional cyclical variables, however, does not solve the problem.

As a last resort, some further constraints were imposed on the estimated equations. Specifically, equation (6) of table 6 assumes that the elasticity of output with respect to private and public capital are the same (a = c), while equation (7) assumes both that the elasticities are the same (a = c) and that the production function evidences constant returns to scale (a + a + b = 1). Neither set of constraints seemed to cause any problem and the latter produces results that are somewhat more consistent with observed income shares.

Having estimated values for a, b, and c, the next step is to recalculate multifactor productivity using these values and the growth in labor, private capital and public capital. Because of the variability in the estimated and implied elasticities of private capital and labor, two separate calculations were made. The

Table 8

Average Annual Percent Change in Multifactor Productivity of Private Nonfarm Business Sector, Selected Periods, 1948–87

Period	BLS	Including Public Capital and Quality-Adjusted Labor Option A[a]	Option B[b]
1948–87	1.1	.8	1.1
1948–69	1.8	1.0	1.2
1969–87	.4	.6	.9
1948–60	1.7	.9	1.2
1960–69	1.8	1.1	1.4
1969–79	.4	.5	.8
1979–87	.4	.7	.9
1948–53	2.5	2.1	2.3
1953–60	1.2	.0	.3
1960–69	1.8	1.1	1.4
1969–73	1.1	1.0	1.4
1973–79	−.1	.2	.4
1979–87	.4	.7	.9

[a]Option A assumes the coefficients for private capital, labor, and public capital are 0.34, 0.32, and 0.34, respectively.
[b]Option B assumes that the coefficients for private capital, labor, and public capital are (0.66 x 0.35), (0.66 x 0.65), and 0.34, respectively.
Source: U.S. Bureau of Labor Statistics and author's estimates.

first was based on the coefficients from equation (7), which implies

A) % MFP growth = % Q growth − 0.34(% K growth) − 0.32(%L growth) − 0.34(% G growth).

The second alternative was based on the assumption that the elasticities of the private factors of production are proportional to their shares of total income. This means that the elasticity of output with respect to public capital was assumed to equal 0.34, and the remaining portion (0.66) was divided proportionately between private capital and labor. This means that

B) % MFP growth = % Q growth − (0.35 x 0.66) (% K growth) − (0.65 x 0.66)(% L growth) − 0.34 (% G growth).

Both reestimated series also include quality-adjusted labor input.

Table 8 shows the average annual percent changes in the reestimated measures of multifactor productivity and compares them with the original BLS index. The BLS multifactor productivity measure slows from an annual rate of increase of 1.8 percent before 1969 to 0.4 percent annually after 1969. Part of that decline can be explained by the slower output growth in the last 20 years; in fact, based on the pre-1969 relationship between output growth and productivity increases, one would have expected multifactor productivity growth of 1.3 percent in the post-1969 period. That is, a 0.5 percentage drop in multifactor productivity growth would have been expected. Instead, multifactor productivity growth declined by 1.4 percentage points, which means that nearly a full percentage point decline in multifactor productivity remains unexplained.

Once public capital is included in the production function, the decline in multifactor productivity growth is much more in line with expectations. The results imply that much of what had been attributed to multifactor productivity growth in the first half of the period really reflected increased output that was due to the buildup of public infrastructure. And much of the decline in multifactor productivity growth after 1969 has reflected the near cessation of public investment. In other words, much of the drop in published multifactor productivity numbers may reflect the omission of public capital from the calculation of inputs rather than a decline in technological innovation.

Much of the drop in published multifactor productivity numbers may reflect the omission of public capital from the calculation of inputs rather than a decline in technological innovation.

The lack of a serious decline in multifactor productivity does not negate the documented decline in the growth of labor productivity from 2.5 percent over 1948–69 to 1.1 percent over 1969–87. Labor productivity growth did slow by 1.4 percent and was responsible for a dramatic slowdown in the growth of wages and living standards. What the foregoing analysis demonstrates is that, contrary to the figures shown in table 1, the entire decline is not attributable to a fall in multifactor productivity. Rather, of the 1.4 percentage point decline in the growth of labor productivity, only 0.3 percent can be attributed to slower multifactor productivity growth and 1.1 percent is due to the decline in the rate of growth in the public capital-labor ratio. This ratio, which grew at an average annual rate of 2.9 percent over 1948–69, did not increase at all during the 1969–87 period.

V. Conclusions

What does all this discussion imply for labor productivity growth in the 1990s and thereafter? First, the data presented in table 1 show that labor productivity growth has already rebounded from the very slow growth experienced in the 1970s. While labor productivity growth averaged only 0.5 percent during the 1973–79 period, it has risen at a rate of 1.2 percent per year since 1979. Observers who simply extrapolate the poor 1970s performance into the future are making a mistake.

One factor contributing to the rebound is a return to the historic rate of growth in the private capital-labor ratio, now that the baby boom generation has been absorbed into the labor force. The average annual increase in the private capital-labor ratio, which had dipped to 1.7 percent between 1973 and 1979, has now returned to historic levels of slightly greater than 2 percent. The other factor contributing to the rebound in labor productivity growth is the turnaround in the growth of multifactor productivity. Even when properly calculated from a production function that includes public capital, multifactor productivity growth showed a sharp drop during the 1970s. Growth has now returned to more traditional levels. The public capital-labor ratio, however, continues to decline, acting as a drag on the growth in labor productivity. The public capital-labor ratio, which had been increasing until 1973, fell by an average annual rate of 0.5 percent over the period 1973–79 and continued to fall by 0.4 percent annually over 1979–87.

What rates of growth in output per worker can we expect in the 1990s and beyond? Assuming conservatively that multifactor productivity growth stays simply at its current level of 0.9 percent (table 8, option B) and the growth of the private capital-labor ratio remains at its post-World War II average of 2.1 percent, labor productivity should grow at 1.4 percent annually.

This number will be lower, however, if investment in public capital continues to fall behind the growth in labor. Currently, the shortfall in public investment appears to be dragging down labor productivity growth by roughly 0.1 to 0.2 percentage points. Simply raising the growth in public capital to the level of the growth in labor input would eliminate this drag. Increasing investment in public capital so that the public capital-labor ratio increased by 1.0 percentage points annually, could raise labor productivity growth to 1.7 percent annually. Investing in public capital to the point where the public capital-labor ratio grew at the same rate as that for private capital could raise the annual growth of labor productivity to 2.1 percent.

The options are clear and manageable. The drop in labor productivity has not been due to a decline in the growth of some mystical concept of multifactor productivity or technical progress. Rather, it has been due to a decline in the growth of public infrastrucure. Policymakers have direct control over the means to reverse this decline. The need to do so is also evident. Collapses of bridges and highways seem to provide ample evidence that the United States has not been maintaining its public capital, much less undertaking any enhancements.

To prevent any further deterioration in the nation's infrastructure, the United States needs to start repairing and constructing. The new public spending need not equal the rates observed following World War II when major improvements were undertaken, but it does need to substantially exceed the current inadequate efforts. This renewed growth in public capital will not only stop the erosion, but will also raise the rate of growth in capital per worker and thereby labor productivity growth. Although suggesting any particular number for the future is necessarily speculative, with renewed efforts to rebuild the public infrastructure there is no reason why labor productivity growth should not return to the 1.7 percent average that the United States has enjoyed on average for most of the 20th century.

Increasing government spending for public capital in an era of large structural federal deficits and financial pressures on state and local governments is a difficult task. But failing to do so will result in serious additional burdens for our children and lower levels of productivity growth than Americans should otherwise expect.

[1] The following discussion draws heavily from Rees (1980).

[2] Moving from equation (1) to equation (2) involves a little rearranging of the terms. Differentiating (1) $Q(t) = MFP(t)f[K(t), L(t)]$ with respect to t yields:

$$\text{(1a)} \qquad \dot{Q} = M\dot{F}Pf(K,L) + MFP(t)[(df/dK)\dot{K} + (df/dL)\dot{L}].$$

Dividing by Q(t) yields:

$$\text{(1b)} \quad \dot{Q}/Q(t) = M\dot{F}P/MFP(t) + (MFP(t)/Q(t))(df/dK)\dot{K} + (MFP(t)/Q(t))(df/dL)\dot{L}.$$

Remembering that $Q(t) = MFP(t)f(K,L)$ yields:

$$\text{(1c)} \quad \dot{Q}/Q(t) = M\dot{F}P/MFP(t) + [(df/dK)/f(K,L)]\dot{K} + [(df/dL)/f(K,L)]\dot{L}.$$

Multiplying the second term by K(t)/K(t) and the third by L(t)/L(t) yields:

$$\text{(1d)} \quad Q/Q(t) = M\dot{F}P/MFP(t) + [((df/dK(t))K(t))/f(K,L)](\dot{K}/K(t)) + [((df/dL(t))L(t))/f(K,L)](\dot{L}/L(t)).$$

Setting $s_k = [((df/dK(t))K(t))/f(K,L)]$ and
$s_l = [((df/dL(t))L(t))/f(K,L)]$ yields:

$$\text{(2)} \qquad \dot{Q}/Q(t) = M\dot{F}P/MFP(t) + s_k\dot{K}/K(t) + s_l\dot{L}/L(t).$$

[3] With competitive factor markets and constant returns to scale:

$$df/dK(t) = p_k \text{ and } df/dL(t) = p_l$$
$$f(K,L) = p_kK(t) + p_lL(t)$$

and the weights are equal to:

$$s_k = \frac{p_kK(t)}{p_kK(t) + p_lL(t)}$$

$$s_k = \frac{p_lL(t)}{p_kK(t) + p_lL(t)}$$

$$s_k + s_l = 1$$

where: p_k = rental price of capital
p_l = price of labor.

[4] Subtracting L/L(t) from both sides of equation 2 yields:

$$\dot{Q}/Q(t) - \dot{L}/L(t) = M\dot{F}P/MFP(t) + s_k\dot{K}/K(t) + s_l\dot{L}/L(t) - \dot{L}/L(t)$$
$$= M\dot{F}P/MFP(t) + s_k\dot{K}/K(t) + (s_l - 1)\dot{L}/L(t).$$

Remembering $s_l - 1 = -s_k$ yields:

$$\dot{Q}/Q(t) - \dot{L}/L(t) = M\dot{F}P/MFP(t) + s_k\dot{K}/K(t) - s_k\dot{L}/L(t)$$
$$= M\dot{F}P/MFP(t) + s_k(\dot{K}/K(t) - \dot{L}/L(t)).$$

[5] *Availability of Productivity Measures for Major Sectors of the Economy*

Productivity Measure	Input	Index Availability	Dates Available
Output per hour of all persons:			
Total Private[a]	Labor	Annually	1909 to present
Nonfarm	Labor	Annually	1909 to present
Farm	Labor	Annually	1909 to present
Business[b]	Labor	Quarterly	1947 to present
Nonfarm business	Labor	Quarterly	1947 to present
Nonfinancial corp.	Labor	Quarterly	1947 to present
Manufacturing	Labor	Quarterly	1947 to present
Durable	Labor	Quarterly	1947 to present
Nondurable	Labor	Quarterly	1947 to present
Multifactor productivity:			
Private business	Labor, capital	Annually	1948 to present
Private nonfarm business	Labor, capital	Annually	1948 to present
Manufacturing	Labor, capital	Annually	1948 to present
KLEMS[c] multifactor productivity:			
Manufacturing and 20 2-digit SIC manufacturing industries	Labor, capital, energy, materials, services	Annually	1948 to present

[a] "Total Private" differs from "Business" in that it excludes government enterprises. In 1981, output of government enterprises consisted of 2 percent of total business output.

[b] Includes government enterprises; private business labor productivity and multifactor productivity measures exclude such enterprises.

[c] Capital (K), labor (L), energy (E), materials (M), and purchased services(S) as inputs.

[6] Baily (1986) provides a brief and comprehensive overview of the literature.

[7] Hours worked for each cohort was calculated from BLS unpublished Current Population Survey data using the following equation:

Hours = A*W*(C/D),
where: A = annual average number of persons at work in nonagricultural industries
W = annual average weekly hours worked in nonagricultural industries
C = annual average number of employed persons in private nonfarm business (government workers, private household workers excluded)
D = annual average number of employed persons in nonagricultural industries.

[8] For a detailed explanation of the calculation of capital services, see U.S. Bureau of Labor Statistics (1983), Appendix C.

[9] The contribution of public capital to the overall equation is a little difficult to discern from the results reported in table 6. The problem is that the equations as originally estimated had very low Durbin-Watson (DW) statistics, signalling the presence of significant positive serial correlation in the residuals of the equation. To deal with this problem, the equations were re-estimated with a correction for first order autocorrelation and the corrected results are shown in table 6. This correction significantly reduces the standard errors of the equations containing only private capital, while it improves the precision of the equations with public capital only slightly. Therefore, the gain from the introduction of public capital is not evident in a reduction in the standard error, but rather in the reduction in the size and significance of the rho coefficients.

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