turns to an examination of the appropriate role of government policy in enhancing the economy's sustainable long-run growth rate. The chapter concludes with a brief assessment of the outlook for trend productivity growth and for the growth of the economy's potential.

FACTORS GENERATING GROWTH OF POTENTIAL GDP

Between 1963 and 1994 real U.S. GDP increased at an average annual rate of 3.1 percent per year. Because the economy appears to have been operating about at its potential in both those years, the average rate of growth of *actual* output between those dates should provide a relatively accurate estimate of the average rate of growth of *potential* output during the same period.

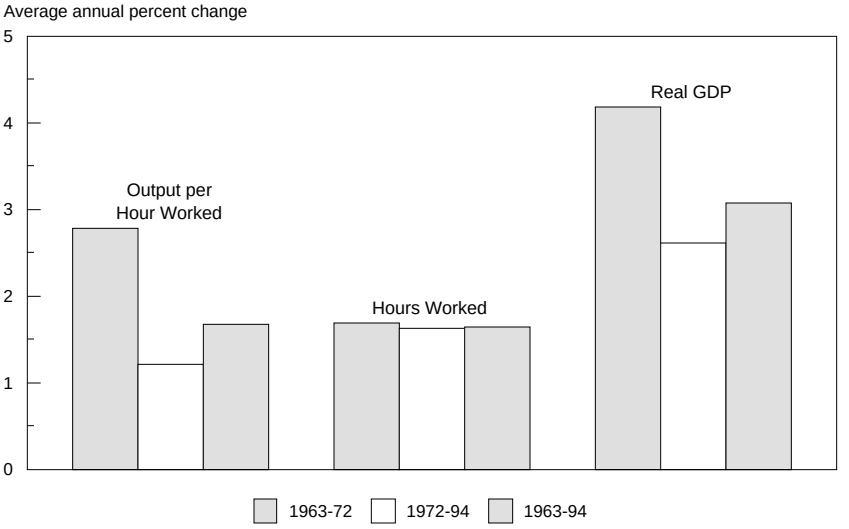
Growth of real GDP can be decomposed into two main components: growth of output per hour worked (or productivity) and growth of hours worked. As Chart 3–2 illustrates, these two components each contributed 1.7 percentage points to the growth of GDP between 1963 and 1994. (Strictly speaking, the data on productivity and hours worked pertain only to the private nonfarm business sector, whereas the data on output pertain to the total economy. As a result, and because the output of the private nonfarm business sector was increasing slightly more rapidly than the output of the total economy, the growth of output per hour and the growth of hours worked add up to slightly more than the growth of GDP).

Chart 3–2 also shows that the average experience since 1963 subsumes two very different episodes. Between 1963 and 1972 real GDP increased at an average annual rate of 4.2 percent. By contrast, since 1972 real GDP has increased only about 2.6 percent per year. (The economy appears to have been operating at about its potential in 1972; as a result, that year should also serve as a useful benchmark for purposes of estimating potential GDP growth rates.) The slower rate of growth of GDP since 1972 can be attributed to a slowdown in the rate of growth of productivity, since the growth of hours worked was about as rapid after 1972 as before.

Chart 3–3 examines the slowdown in the growth of productivity in more detail. The chart illustrates one of the most significant economic developments of the postwar period. Whereas productivity in the private nonfarm business sector increased at an average annual rate of 2.8 percent between 1963 and 1972, it increased only 1.7 percent per year between 1972 and 1978, and only 1.0 percent after 1978 (yet another year in which the economy was operating close to potential).

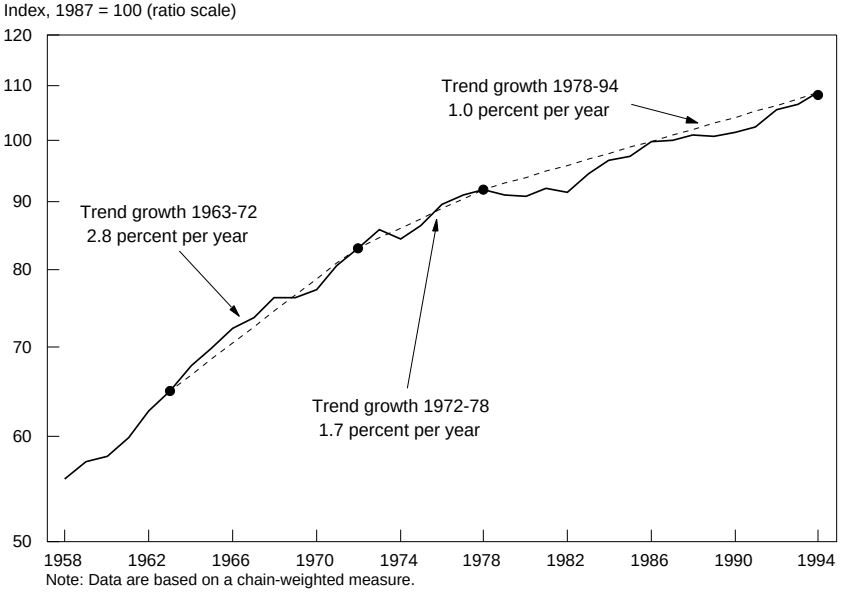
By contrast, productivity growth in the manufacturing sector seems to have slowed much less during the past four decades. As

Chart 3-2 **Factors Generating Growth of Gross Domestic Product**
Since 1972, real GDP has increased more slowly than before, owing to a reduction in the rate of growth of output per hour worked.



Note: Estimates of growth in output and output per hour are based on chain-weighted measures. Data on output per hour and hours worked pertain to the private nonfarm business sector, whereas the data on GDP pertain to the whole economy.
Sources: Council of Economic Advisers, Department of Commerce, and Department of Labor.

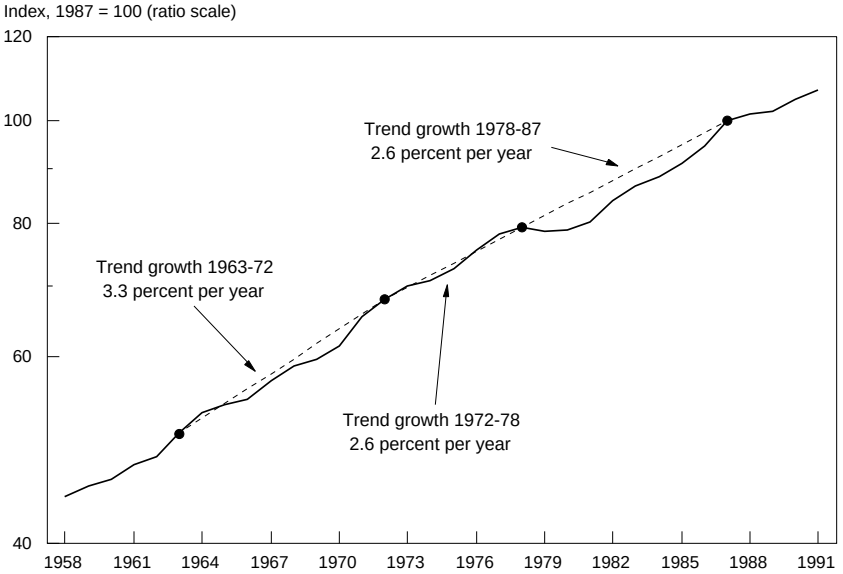
Chart 3-3 **Output per Hour in the Private Nonfarm Business Sector**
Productivity growth in the private nonfarm business sector seems to have slowed markedly sometime in the early 1970s.



Note: Data are based on a chain-weighted measure.
Sources: Council of Economic Advisers and Department of Labor.

Chart 3–4 shows, output per hour in the manufacturing sector is estimated to have increased on average about 3.3 percent per year between 1963 and 1972, 2.6 percent between 1972 and 1978, and 2.6 percent again between 1978 and 1987. (The chain-weighted data used in Chart 3-4 were only available through 1991. Growth in manufacturing productivity between 1987 and 1991 was quite weak, but this is not surprising given that the economy was still in recession in early 1991. Assessment of the more recent trend in manufacturing productivity will have to await publication of data for subsequent years, when the economy was once again operating closer to potential.)

Chart 3-4 **Output per Hour in the Manufacturing Sector**
Productivity growth in the manufacturing sector appears to have slowed only a little since the 1960s and early 1970s.



Note: Data are based on a chain-weighted measure.
Source: Department of Labor.

Taken together, Charts 3–3 and 3–4 suggest that the slowdown in the growth of productivity after 1972 was concentrated outside the manufacturing sector. It has been argued that these and similar data exaggerate that concentration, because they do not control for the fact that the manufacturing sector may have increasingly "outsourced" some low-productivity activities. For example, if factories contract with security firms to do work formerly done by their own security guards, that activity will be counted in the services rather than the manufacturing sector, and if security guards' productivity is less than that of the factories' assembly-line workers, official statistics may report an increase in overall manufactur-

ing productivity that does not reflect an increase in the productivity of any individual worker. What this argument ignores, however, is that *high*-productivity jobs may also have been outsourced, in which case the direction of bias in the official estimates would be ambiguous. On balance, the evidence suggests that the apparent strength of productivity growth in manufacturing is not a figment of job migration.

Much of the discussion in this chapter focuses on the slow rate of growth of productivity in the United States since the early 1970s, relative to earlier U.S. experience and the experience of other countries. But it is worth noting that U.S. workers remain among the most productive in the world. This suggests that the productivity "problem" in the United States has much more to do with the rate of growth of productivity than with its level. Box 3–2 discusses one possible explanation for the coincidence of a high level and slow growth of productivity in the United States compared with other countries.

FACTORS GENERATING GROWTH OF PRODUCTIVITY

Productivity can be raised by improving the quality of the work force (adding human capital per worker in the form of education or training); by increasing the quantity of capital (investing in new private equipment and structures and in public infrastructure); and by improving the efficiency with which these factors of production are used. Improvements in efficiency can come from advances in technology (due to basic research or applied research and development, or R&D), but they can also come from other sources, such as process innovation, that are not conventionally thought of as technology. Chart 3–5 summarizes the behavior of the main factors contributing to the growth of productivity since 1963. (Box 3–3 discusses whether an increase in productivity comes at the expense of a reduction in jobs.)

THE QUALITY OF THE WORK FORCE

One important determinant of worker productivity is the workers themselves and the skills and abilities they bring to the workplace. Increases in the hourly output of the average worker can reflect an improvement in the characteristics that allow workers to accomplish the same tasks in less time, to adapt to changing situations with greater flexibility, and to become the engineers of change themselves.

Two rough indicators of work force quality are average educational attainment (average years of schooling per worker) and average experience. Since 1963 the average educational attainment of

Box 3–2.—Technological Catch-up and International Differences in Productivity Growth

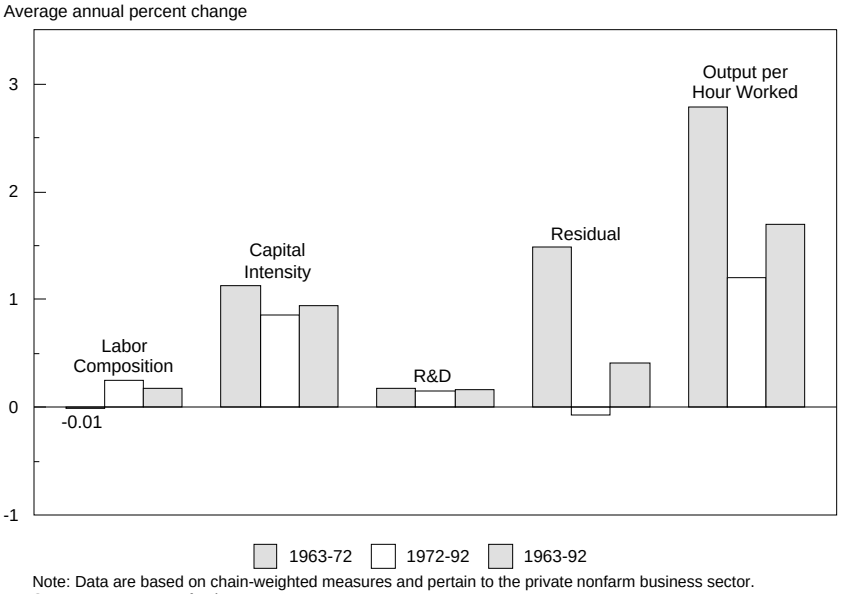
How could it be that the United States, with one of the highest *levels* of productivity in the world, is not also among the countries where productivity is growing most rapidly? Some economists have suggested that, far from being a paradox, this circumstance is to be expected. The slow-growing leader, fast-growing follower pattern may simply reflect the dynamics of technological "catch-up."

Standard models of economic growth assume that richer and poorer countries have the same production technologies at their disposal (even if they choose to implement them with different mixes of capital and labor). Recently, however, growth economists have begun to question the realism of this assumption. In practice, technological diffusion—the spread of ideas—from leader to follower is far from automatic. Firms in follower countries may lack the skilled workers (engineers, managers) needed to exploit technologies used in leader countries efficiently. In addition, firms in leader countries may attempt to guard their core technologies to prevent or delay their spread to potential competitors abroad. Technological diffusion may be particularly slow in the case of "soft" technologies (process technologies and work organization), which cannot be imported and reverse-engineered as new products can.

For follower countries a gap in technology creates an opportunity. Leader countries (such as the United States) will find their productivity growth limited by the rate of creation of new knowledge. But followers can grow more quickly by closing a portion of the technology gap. It appears that success in closing this gap helped spur the postwar growth of Japan and the East Asian newly industrializing countries, which invested heavily in technology acquisition and human resources and created business environments conducive to technological growth. Not every country succeeds, however, in closing the technology gap. Indeed, some followers have fallen farther behind, and follower countries as a group have not become richer faster than leader countries. Nevertheless, the evidence suggests strongly that, for followers, the upper limit on growth in per capita income and productivity exceeds that for technological leaders.

the work force has increased by about 2 years. The Bureau of Labor Statistics (BLS) of the Department of Labor estimates that investment in education boosted productivity about 0.3 percentage point per year, on average, between 1963 and 1992. In contrast, the average experience level declined slightly between 1963 and 1992,

Chart 3-5 **Factors Generating Growth of Output per Hour**
Most of the slowdown in productivity growth after 1972 reflects a deceleration of the so-called residual factor.



Note: Data are based on chain-weighted measures and pertain to the private nonfarm business sector.
Source: Department of Labor.

knocking about 0.1 percentage point off productivity growth each year. On net, therefore, measured changes in worker quality have added an estimated 0.2 percentage point per year to productivity growth since 1963. Interestingly, worker quality appears to bear none of the responsibility for the post–1972 slowdown in productivity growth. In fact, the estimated contribution of improvements in worker quality to productivity growth *increased*, from essentially nothing before 1972 to about 0.3 percentage point per year between 1972 and 1992 (Chart 3–5).

One caveat is in order here. Although the BLS education measure captures changes in the average number of years of schooling, it does not capture changes in its quality. Clearly, quality matters: a worker who spent 12 years marking time in poorly taught classes is likely to be less productive than one who spent the same number of years actively learning from skilled teachers. Unfortunately, the evidence on whether any such decline in the quality of schooling could help explain the productivity slowdown is too scanty to support any firm conclusions.

Training workers on the job is another way of increasing their human capital and contributing to aggregate productivity growth. Solid quantitative estimates have not been made of the contribution of training to aggregate productivity growth because there are no reliable data on the aggregate amount of training taking place.

Box 3–3.—Productivity and the Growth of Jobs

A persistent concern, voiced by many workers and business owners as well as some economic analysts, is that rapid growth of productivity may cause job losses. This concern seemed validated early in the current expansion, when strong growth of productivity seemed to be standing in the way of a vigorous pickup in the pace of hiring. Does this concern have any analytical basis?

At the macroeconomic level, a pickup in the rate of productivity growth need not be associated with any reduction in the aggregate number of jobs available in the economy—at least not once fiscal and monetary policy have been adjusted to reflect the favorable change in productivity growth. An increase in productivity growth allows GDP to grow more rapidly without generating inflationary pressures. Over the long term, macroeconomic policies can bring the growth of aggregate demand in line with the improved rate of expansion of the economy's productive capacity, and thus sustain the growth of employment.

At the microeconomic level, productivity growth may change the composition of available jobs, and thus may be associated with significant dislocation as workers are forced into new jobs, possibly requiring different skills and perhaps even relocation. In this context, the role of government is to facilitate the transition of workers and capital to their most productive uses, while setting fiscal and monetary policies to keep the economy on a sustainable trajectory of high employment with low inflation.

Nevertheless, available microeconomic evidence suggests that training matters. Studies of the wages of individual workers indicate that the payoff to formal training (including apprenticeships) can be quite substantial: a year of training typically provides returns of a similar magnitude to those offered by a year of formal schooling (an increase in wages of about 6 to 10 percent on average). Other research has found that companies offering more training enjoy higher rates of productivity growth. (Chapter 5 discusses the importance of worker training in greater detail.)

THE SIZE OF THE PRIVATE CAPITAL STOCK

Increasing capital intensity—roughly speaking, the amount of capital per worker—has been a key source of productivity improvement over the postwar period. When new investment has been undertaken to support an improved technology, the gains have some-

times been especially impressive. For example, output per hour in the telecommunications industry increased an average of 5.5 percent per year between 1969 and 1989, as the industry invested heavily in new satellite, cellular, and fiber optic technologies.

Productivity increases through capital investment have often involved exploiting economies of large-scale production. Industries such as food processing, beverages, and electricity generation are cases in point. In the beverage industry, for example, high-speed canning lines have raised productivity, but their contribution has been made possible in part by the development of large markets. To operate efficiently, these lines must produce nearly 500 million cans per year!

Data from the BLS indicate that increases in capital intensity—also known as capital deepening—added about 0.9 percentage point per year to the growth of U.S. productivity between 1963 and 1992. As Chart 3–5 shows, a reduction in the pace of capital deepening explains only a small portion of the post–1972 slowdown in productivity growth.

INFRASTRUCTURE

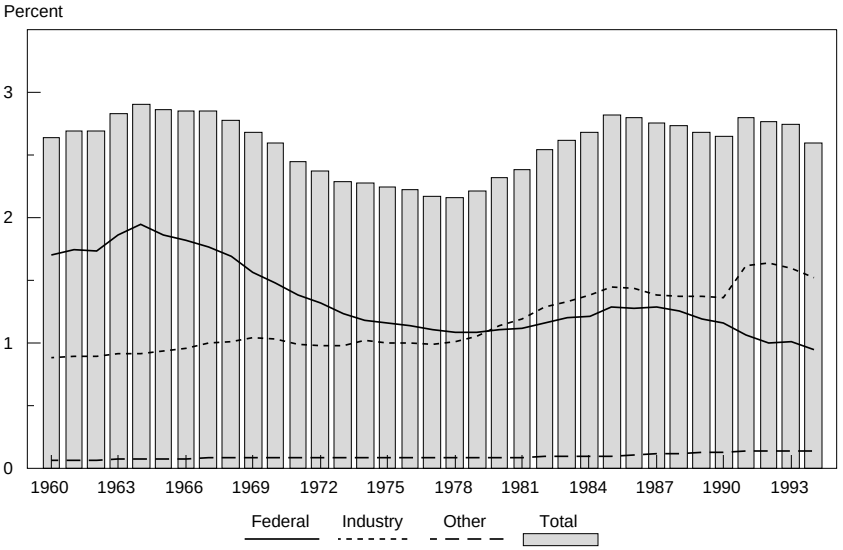
Historically, investment in public capital such as roads, bridges, airports, and utilities has made a significant contribution to the Nation's productivity growth. Yet the net public capital stock in the United States has declined relative to GDP, from 50 percent of GDP in 1970 to only a bit more than 40 percent recently. The net public capital stock has also declined relative to the net private nonresidential capital stock. These declining trends in public capital suggest that infrastructure investment has been a net drag on the growth of productivity since 1970, but there is no consensus as to the quantitative importance of this effect.

RESEARCH AND DEVELOPMENT

Total Federal and private spending for research and development has averaged about 2½ percent of GDP since 1960 (Chart 3–6). In dollar terms, American investment in R&D in 1992 was greater than the R&D investment of Japan, Germany, and France combined. Even relative to national income, the United States was roughly tied with Japan for first place among major industrialized countries.

As Chart 3–6 shows, a much larger share of total R&D spending in the United States is privately financed now than used to be the case. Relative to GDP, Federal spending for R&D was at a high level in the early 1960s, after the Sputnik launch provoked a wave of concern that the United States was lagging behind the Soviet Union technologically. But that ratio trended down during most of the 1960s and 1970s and has been more or less flat since the late

Chart 3-6 **Expenditures for Research and Development Relative to GDP**
Total R&D expenditures have been fairly steady over the past three decades, but the share financed by private industry has risen since 1980.



Note: "Other" includes R&D funded by universities and other nonprofit organizations. Observations after 1990 are not strictly comparable with those of earlier years, due to a change in the survey methodology.
Sources: Council of Economic Advisers and the National Science Foundation.

1970s. In contrast, industry-funded R&D investment has been noticeably greater relative to GDP during the 1980s and early 1990s than during the 1960s and 1970s. Indeed, since 1980 the private sector has sponsored more R&D than has the Federal Government.

According to BLS estimates, investment in R&D contributed about 0.2 percentage point to the growth of productivity between 1963 and 1992, with essentially no difference before and after 1972 (Chart 3–5). In all likelihood, however, R&D has played a more important role than these estimates would indicate, for a number of reasons. First, given the difficulties involved in measuring the return to investment in R&D, part of it probably shows up in the unexplained residual (see below). Second, because it is very difficult for anyone investing in R&D to capture all of the benefits of that investment, part of the return to American investment in R&D probably is captured by foreign producers. (Similarly, American producers probably capture some of the benefits of R&D investment undertaken by foreign firms.) Finally, some investment in R&D has had important benefits in addition to whatever improvement in the measured growth of productivity it may have yielded. For example, medical research (which claims 18 percent of total U.S. R&D) has substantial payoffs, but it is highly unlikely that these payoffs are fully reflected in the statistics on output per hour.

THE RESIDUAL

Over the postwar period, increases in human and physical capital and investment in R&D fail to account for all of the measured growth in productivity. The remainder generally is presumed to reflect unmeasured improvements in the quality of the capital stock and the work force, as well as more efficient utilization of capital and labor in the production process. Available data suggest that this unexplained residual contributed about 0.5 percentage point per year to the growth of productivity between 1963 and 1992.

The nature of this residual has puzzled economists for 40 years and has stimulated a vast literature seeking to explain it and to understand the dramatic difference in its behavior before and after 1972. Between 1963 and 1972 the residual contributed about 1.5 percentage points per year to the growth of productivity. Between 1972 and 1992, however, the residual made no contribution at all (Chart 3–5).

Two possible explanations as to the source of the residual follow from the previous discussion. The data from the BLS do not quantify the effect of either on-the-job training or investment in infrastructure, so any contributions of those two factors end up in the residual. In addition, industries evolve in ways that increase productivity, and the contributions of these evolutions are not captured in existing measures of capital, labor, or R&D investment. For example, the shift from small food stores to supermarkets gave a substantial boost to productivity in food retailing in the United States in the 1950s and 1960s. Similarly, many American companies have improved their business systems, and the contributions of these improvements are likewise not captured in the official statistics except, by default, in the residual. For example, the redesign of production processes within the manufacturing sector (such as lean manufacturing of automobiles) and the redesign of products to make them easier to assemble have been sources of productivity growth.

Some observers have argued that an increasing burden of government regulation may account for part of the reduction in the contribution of the residual during the 1970s. Since the late 1970s, however, a number of important industries—including trucking, airlines, and rail—have been deregulated. In addition, competition has been introduced into the market for long-distance telephone services. These factors suggest that any role of regulatory burden in the post–1972 productivity slowdown probably has not been large.

Another commonly mentioned explanation for the reduction in the contribution of the residual to productivity growth is the rise in energy prices during the 1970s. According to this logic, efforts to reduce energy consumption reduced measured productivity

growth. This explanation is not very convincing, however, because energy costs do not bulk large in total costs, and because productivity growth has not revived despite the reversal of most of the 1970s runup in real oil prices.

Finally, it is possible that part of the slowdown in *measured* productivity growth is not real but reflects measurement error. This could be the case if, for example, measurement error has caused the official statistics to understate productivity growth by more since 1972 than before. Even if measurement error does not help explain why productivity growth has been slower since 1972 than before, it may help explain why it has been so slow in absolute terms. A later section of this chapter examines the extent to which the productivity problem might reflect faulty measurement.

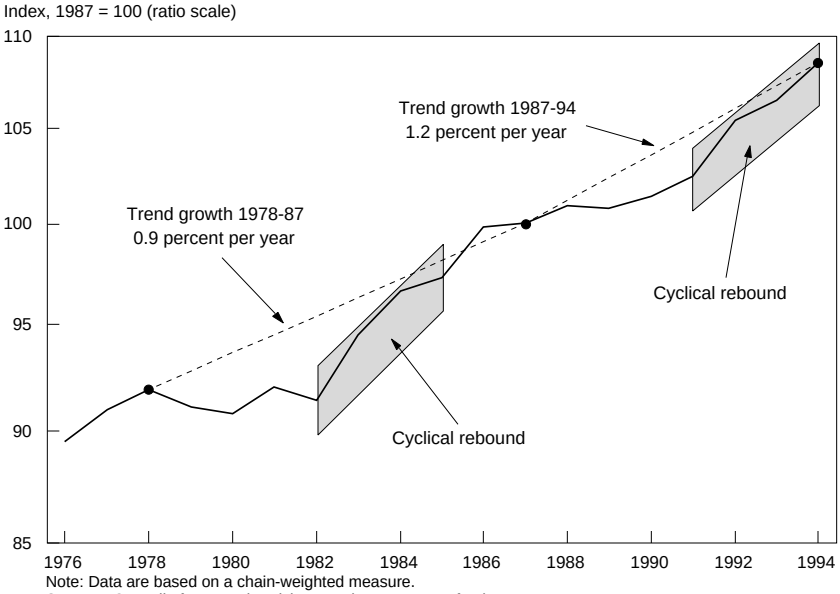
HAS THE TREND IN PRODUCTIVITY GROWTH IMPROVED RECENTLY?

Since 1987, according to current estimates, productivity growth in the private nonfarm business sector has averaged 1.2 percent per year, somewhat faster than the average during the previous decade. And since 1991, productivity growth has averaged about 2.0 percent per year—more than twice the 1978–87 average. Are recent claims of a pickup in trend productivity growth justified? (Provided there has been no offsetting reduction in the growth of hours, such a pickup would translate into an increase in the economy's potential growth rate.) This question is not easily resolved because the recent behavior of productivity has been heavily influenced (for the better) by the faster pace of economic activity during the last 2 years. A proper assessment of the trend in productivity growth can be made only by abstracting from cyclical influences.

Chart 3–7 focuses on the behavior of productivity since 1976. Between 1978 and 1982—a period that included the deepest recession of the postwar period—productivity actually declined slightly according to official estimates. Then, as recovery took hold, productivity rebounded. By 1987 the economy once again was operating in the neighborhood of its full potential. Between 1978 and 1987 the growth of productivity averaged about 0.9 percent per year.

Since 1987 this chain of events has essentially repeated itself: a period of slow growth in productivity as the economy endured a recession, followed by a period of rebound as the recovery gathered strength. Today, well into the expansion, the economy once again appears to be operating in the neighborhood of its potential. Between 1987 and 1994—as was noted above—productivity growth averaged about 1.2 percent per year. Thus, currently available data do seem to hint that the trend in productivity growth has picked up in the last few years. However, the magnitude of that pickup

Chart 3-7 **Output per Hour in the Private Nonfarm Business Sector**
Productivity has increased rapidly since 1991. Nonetheless, it is still difficult to know whether there has been an improvement in the trend rate of productivity growth.



Note: Data are based on a chain-weighted measure.
Sources: Council of Economic Advisers and Department of Labor.

pales in comparison to the decline that occurred earlier in the postwar period. Moreover, the evidence in support of a pickup is still inconclusive. For example, if trends are computed for the periods 1978–86 and 1986–94 rather than 1978–87 and 1987–94, the suggestion of a pickup is much weaker: productivity growth averaged 1.0 percent per year in the earlier alternative subperiod and 1.1 percent in the later one. On the other hand, if the breakpoint chosen is 1988 or, especially, 1989, the evidence in favor of a pickup appears stronger. However, the averages over these later periods, especially the one since 1989, are dominated by the cyclical recovery and so may create a false impression of an improvement in the trend.

Furthermore, the Labor Department released data in 1994 suggesting that the growth of hours worked between 1993 and 1994 may be revised upward by enough to shave 0.1 percentage point off the average rate of productivity increase for the period 1987–94. Thus, while the evidence in favor of a slight improvement in the productivity growth trend is encouraging, it is not yet decisive. The experience of the next few years will be quite telling for this issue.