Perspectives on Productivity

"The New Economy in a New Century: Impacts of Technology on What and How We Teach"
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What in the world has happened in the United States to raise economic growth so substantially during the last few years? Real output has risen beyond virtually all forecasts; unemployment has fallen to levels that only a few years ago were thought to be unattainable; labor productivity growth has increased to rates last experienced many years ago, during the "Golden Age" of 1950-73; and inflation has remained low and even fallen slightly. This unlikely coincidence of economic outcomes has led some observers to conclude that the economy has entered a "New Age." In this age, technical progress in information and communication technology—often referred as "ICT" for short— has, some believe, removed all previous speed limits on the economy. From this time forward, potential real output will grow more rapidly than in the past, and the unemployment rate will be forever lower. And, even more remarkably, these events will occur without any expansionary monetary policy that might raise fears of higher inflation.

Perhaps I've offered an overblown picture of the story some tell, but my characterization is not overblown by much. My goal tonight is to bring some perspective to these events by asking how unusual they are within both U.S. history and relative to the experience of other countries during the 1990s. I'll concentrate on the productivity part of the story, for that part has certainly captured everyone's attention. I will distinguish carefully between labor productivity and total factor productivity. This issue may sound technical, but we must dig into it if we are to make progress in understanding the key disputes over whether we really are, or are not, living in a "new" economy.

Before proceeding, I want to emphasize that the views I express here are mine and do not necessarily reflect official positions of the Federal Reserve System. I thank my colleagues at the Federal Reserve Bank of St. Louis for their comments—especially Dick Anderson, who is a coauthor of this speech. I retain full responsibility for errors.

MEASURING PRODUCTIVITY: AVERAGE LABOR PRODUCTIVITY

To begin our discussion, let me pose this question: What do we mean by "productivity?" The most commonly discussed measure is *labor productivity*. Labor productivity is simply the output of either an industry or the aggregate economy divided by labor input. A *change* in labor productivity reflects any change in output that cannot be accounted for by a change in labor input; such changes may be due, for example, to changes in the amount of capital used per person employed.

I start with this definitional point because most popular discussions of productivity launch right into the analysis of the glorious new economy without noting how important the definition is to the analysis. It takes only half a second of thought to understand that it really matters whether a ditch digger's higher productivity comes from substituting a backhoe for a shovel or for some other reason.

Let's start with a few numbers. Labor productivity growth in the United States has risen during the last several years. Using annual average data, in 1999 labor productivity— output per hour of labor input—increased 3.0 percent in the nonfarm business sector. During 1998, the increase was 2.8 percent; during 1997, 2.0 percent. The growth of labor productivity is not only higher than it used to be, but for each of the three most recent years it has been higher than the previous year.

How unusual is this higher rate of labor productivity growth? The available U.S. historical data, beginning in 1929, show that labor productivity growth is highly volatile. Increases of this size in the annual growth rate for a year or two are not unusual in this record, especially during the early years of business cycle recoveries. But, such increases are highly unusual during the later years of an economic expansion. The most recent *Economic Report of the President*, for example, notes that labor productivity in the nonfarm business sector increased by only 1.3 percent and 1.1 percent per year, respectively, during the final two years of the expansions that ended in late 1969 and 1990.

Longer-run comparisons also suggest that something unusual has occurred. During 1950-73, for example—the so-called "Golden Age" of U.S. productivity growth—labor productivity in the nonfarm business sector increased at a compound average annual rate of approximately 3 percent. From 1973 through 1995, productivity growth slowed to about a 1 percent pace. During the last two years, labor productivity growth has returned to its Golden Age rate. The questions of the day are: Why did labor productivity growth rise? Will the higher rate continue?

One hypothesis is that the resurgence of labor productivity growth is closely connected to the strong pace of business equipment investment during the 1990s, both in the United States and Europe. Angus Maddison, the well-known economic growth historian, has demonstrated strong longer-run correlations among three variables in an economy: the pace of technological innovation, the rate of investment in new physical capital, and the growth rate of labor productivity. He stresses that technological innovations typically are put into service "embodied" in new capital equipment. In contrast, new ways of doing things that enhance the productivity of the existing capital stock rarely have large effects. Strong investment spending before 1973, both in the United States and worldwide, contributed to rapid productivity growth by disseminating new technology. Worldwide investment spending slowed sharply after 1973, and with it worldwide labor productivity growth. The rebound of business investment during the 1990s, both in the United States and Europe, came at a time of major technical progress (and price decreases) in the production of semiconductors and computers. This investment rebound has undoubtedly contributed to the recent increase of labor productivity growth.

Changes in labor productivity in foreign countries provide a second yardstick against which to judge whether the recent growth of U.S. labor productivity is unusual or not. Let me caution you, however, that not all measures of labor productivity are the same. In the United States, the most commonly discussed measure is the one produced by the Productivity Section of the Bureau of Labor Statistics. In this measure, the numerator is the output of the nonfarm business sector and the denominator is total hours of work by employees in that sector. In European publications, however, the most commonly cited measure is the ratio of aggregate real GDP to the number of employed persons. Even more confusing, in some publications, analysts focus on real GDP per capita, rather than per employed person, as a measure of productivity.

A Ph.D. in economics is not required to appreciate that these various measures of labor productivity will differ when variables such as the number of annual hours per employee or the percentage of the working-age population employed differ across countries. The U.S. Bureau of Labor Statistics is one of the few agencies that seeks to adjust for these differences and provide consistent cross-country comparisons.

Unfortunately, due to data limitations, the BLS publishes the comparative statistics only once each year and includes only manufacturing. For the United States, from 1990 to 1998, labor productivity in manufacturing shows a 3.3 percent annual growth rate of output per hour. For certain countries, the rate is more rapid: 4.6 percent for Sweden, 3.9 percent for France, and 3.8 percent for the Netherlands. For some others it is slower: 3.2 percent for Germany, 3.0 percent for Japan and Belgium, 2.2 percent for the United Kingdom, and 2.0 percent for Canada. On an annual basis, the data are erratic: manufacturing productivity growth in the United States, for example, rises to 6.1 percent in 1995, slows to 2.1 percent in 1996, and rises again to 4.1 percent in both 1997 and 1998. In some individual years since 1995, growth rates for other countries again exceed the U.S. rate: 7.2 percent for France and 5.9 percent for Germany in 1997 and 4.3 percent for Germany in 1998.

In part, cross-country differences reflect different stages of the respective business cycles. In addition, fluctuations in international economic conditions make comparisons during the 1990s tenuous. In general, European nations have been more strongly affected by international economic crises such as occurred in Mexico in 1995, East Asia in 1997, and Russia in 1998. On balance, though, comparisons of U.S. and European productivity growth suggest similar patterns.

Additional confirmation of the common impact of ICT technology is evident in a comparison of the analysis in the most recent *Economic Report of the President* with similar analysis in the European Union's December 1999 *Joint Employment Report*. Both reports are concerned with restructuring, layoffs of workers, and the need for "lifelong" education to adapt to a changing world. The EU's *Employment Report* also reviews the large number of initiatives by member nations to promote entrepreneurship in the new "information society," including easing the administrative burdens that hamper job creation by small business.

Finally, I must note that an increasing number of studies have addressed the role of ICT investment in the services industries. Such studies are hampered by the fact that output of these sectors is less well-measured than that of manufacturing. The studies generally have reached similar conclusions, however: Service sectors have extensively purchased new ICT equipment and deployed it to increase labor productivity, both in the United States and Europe.

MEASURING PRODUCTIVITY: TOTAL FACTOR PRODUCTIVITY

To this point, I have concentrated on labor productivity. The contributions to output of other inputs, including physical capital, have been ignored. For some purposes and during some time periods, these omissions might be unimportant. Unfortunately, as I hinted in the introduction of this speech, this is not one of those periods. The outstanding fact of the past decade is the sharp fall in the price of ICT relative to the prices of other productive inputs. To the extent that these price decreases have induced firms to substitute ICT-type capital for labor, the story of the "new economy" is one of input substitution, not productivity growth. Although ditch diggers may not have bigger and better backhoes, most workers have been equipped with better communications equipment, better computers, and better software.

Recall that changes in labor productivity reflect all changes in output that cannot be attributed to changes in labor input. Changes in input prices that induce substitution by firms of capital for labor will increase measured labor productivity. (Of course, if output and sales do not increase sufficiently, higher productivity will also result in fewer workers in that firm or industry, as has been the continuing case in agriculture for 150 years.) These substitutions, however, are not what economists commonly refer to as "technical change," nor are they likely to increase the long-term trend growth of the economy's potential output. Instead, we need to measure the effect of new technology on output *after* accounting for all the growth of input due to increases in *both* capital and labor. The concept of total factor productivity seeks to do so.

Total factor productivity measures changes in output relative to an index number that measures the combined inputs of labor and capital. Changes in total factor productivity reflect changes in the organization of production or in technology that are *not* due to changes in either labor or capital inputs.

The concept of total factor productivity is not new. Economists often refer to TFP as the "Solow residual," following from Robert Solow's seminal 1956 growth theory article. But, to understand TFP, we must back up one step: What do we mean by "capital"? In early growth theory research, such as Solow's 1956 and 1957 articles and Edward Denison's later work on growth accounting, physical capital was taken to be a homogenous input. That is, in the analysis, different vintages of capital were not separated. Many analysts have argued that this was (and is) a serious mistake. New technology is primarily put into use in the form of new physical capital, and differing vintages of capital must be adjusted carefully for their productive capacity. Ironically, Robert Solow himself argued for this point of view in three later articles, published between 1960 and 1963.

In recent econometric studies of total factor productivity, labor and capital inputs have been measured with index-number methods similar to those introduced by the Bureau of Economic Analysis in 1995 to measure real GDP. Such measures are particularly appropriate when several types of each input must be included—such as workers with differing amounts of education or several different vintages of physical capital—and the relative prices of the various inputs are changing. The econometric methods attempt to separate changes in labor productivity into two parts: the part due to the increase in the amount of capital per unit of labor and the part due to organizational changes permitted by new technology. The first part measures the increase in output as a consequence of the application of more capital. The second part is the "Solow residual," that part of additional output which is not accounted for by inputs of labor and capital.

A key finding from this research is that the outstanding fact in the United States since 1995 has been a 28 percent per year decrease in the costs of ICT equipment, quality adjusted. These studies conclude that the overwhelming factor behind the increase in U.S. labor productivity during the 1990s has been the increase in the capital/labor ratio. Although differing in the details, these studies on balance conclude that total factor productivity growth has increased moderately since 1995, and in the past three years has contributed perhaps 0.75 to 1 percentage point of the growth of aggregate real GDP.

If confirmed by further research, these results have important implications for the future. In particular, the results resurrect a common theme in the growth theory literature of the last 45 years: the critical importance of not confusing changes in *levels* with changes in *rates of growth*. Sharp, unexpected decreases in the price of an important input—ICT equipment—may induce a long-lasting, perhaps permanent, increase in the *level* of labor productivity and potential output. But the same decreases may suggest little or no increase, except for near-term adjustments, in the *growth rate* of either labor productivity or potential output. For the growth rate itself to be permanently higher, the rapid decline in the price of ICT equipment and consequent continuing increase in the capital/labor ratio would have to be permanent.

In related, widely publicized research, Robert Gordon has argued that all of the U.S. economy's productivity gain during the 1990s is due to improvements in the production of computers, or more specifically, in the production of the semiconductor components of computers. He argues that most other segments of the economy have experienced little, if any, gain from the use of computers. Although these more recent econometric results suggest somewhat higher total factor productivity growth than Gordon's estimates, they are consistent with Gordon's findings. In sectors outside semiconductor manufacturing, the improvement in computers has induced the substitution of less expensive for more expensive inputs; net (econometrically) of the input substitution effect, most of these sectors have gained little from the new technology. That is, new technology has not shifted the production function in these sectors but has simply led to the application of more capital per unit of labor to the production process. Semiconductor manufacturing, on the other hand, has benefited significantly because the output of that sector—better computers—is a very important input to the same sector: new, more powerful computers are essential to the design and manufacture of even newer, more powerful computers. In turn, these computers will ease the production of even newer machines.

As newer computers continue to enhance our ability to design and build ever more powerful machines, the "per unit" cost of computing likely will continue to decrease. In 1990, the per-unit decrease in the price of computing power was running at approximately a 15 percent annual rate; by the middle of the decade, the price of computing power was falling at nearly a 30 percent annual rate. As the price continues to decrease, it seems likely that much of this new power will be used to manage and catalog knowledge and information on increasingly sophisticated computer networks. (These advances might even reduce the flow of paper across my desk!).

Inexpensive and powerful computers already are permitting the design and implementation of knowledge- and document-management systems at individual-department levels, a luxury that would have been difficult to afford only a few years ago. More powerful computers also will continue to improve communications, permitting faster and more precise transmission of large amounts of information over long distances. The lower cost of high-speed international data links already is permitting major multi-national corporations to better share information around the world in real time, and perhaps has contributed to some of the mega-mergers of recent years. At the same time, the lower price of ICT equipment likely has lowered the costs of starting and operating a small business. Accounting software can replace an accountant; a word processing program can replace a typist; web pages can replace a printed catalog; and e-mail can replace a telephone receptionist.

These developments are obviously extremely important. They will permanently increase the level of labor productivity. But given our current understanding of these issues, they are unlikely to yield a permanently higher growth rate of productivity. It seems probable to me that eventually—although I have no idea when—the technical advances that have been creating the sharp declines in the price of computing power will slow, perhaps as a consequence of fundamental laws of physics that control how many transistors can be packed onto microchips. When the price decline of computing power slows, the application of additional computing power per unit of labor will slow, and so also will the rate of growth of labor productivity. But let me emphasize again that I have no idea when the growth will slow or even if our current understanding of these issues is on target.

HISTORICAL ANALYSIS OF FACTORS IN ECONOMIC GROWTH AND PRODUCTIVITY

I'll conclude my remarks by attempting to place the events of the past decade in the context of international economic history. Although data are incomplete, it seems unlikely that in the past any technology has experienced price decreases of the scale we have recently experienced for ICT equipment and software. Electricity spread fairly rapidly into both homes and factories during the two decades after Edison and Westinghouse agreed on industry standards during the late 1890s. But, following the introduction of these standards, the cost of electrical equipment and appliances didn't decrease sharply relative to other goods or wage rates, during the first quarter of the twentieth century.

The world in the past has experienced sharp fluctuations in productivity growth and likely will again. The historical record suggests, however, that sustaining more than a 2 percent annual growth rate of labor productivity for an extended period is unlikely. Economic historians tell us that the world entered a new "capitalist" era in about 1820. Before then, for centuries, real output per worker had increased very little. Since then, there has been a fairly steady increase in the amount of physical capital per labor hour, and worldwide output (GDP) per person employed has increased more than eight fold. Historians agree that Great Britain was the technological leader up to about 1890; they also agree that labor productivity grew at only about a 1.4 percent annual rate during that period.

About 1890, the United States took the mantle of "technological leader" away from Britain. At a conference of educators, it seems appropriate to note that historians give much of the credit to the U.S. higher education system. The Morrill Act of 1862, which created land grant universities, stimulated teaching and research in both agriculture and engineering. In engineering, within a decade after passage of the Morrill Act, the number of engineering schools went from 6 to 70, and then to 126 by 1917. U.S. engineering schools graduated 100 students in 1870; by 1917, the number was 4,300. As early as 1890, the ratio of university students per 1,000 primary school students in the United States was two to three times that of any other country. In agriculture, as late as 1914, the United States was well behind Europe in scientific agriculture—a generation later, the United States was the world leader.

Since 1890, U.S. productivity growth has not been smooth. Productivity grew most rapidly during 1950 to 1973, when much of the world was catching up, technologically, to the United States. Some of the U.S. growth during this period may have reflected a recovery process after the disruptions of the Great Depression and World War II. The second best period was 1870 to 1913 with about 2 percent annual growth, as the United States was pulling ahead, technologically, of Great Britain. Perhaps surprisingly, the slow 1 percent productivity growth during 1973 to 1992 still ranks that era in third place.

In the best of all worlds, we can only hope that the recent 3 percent annual growth in labor productivity continues. For the United States, the long-run trend of labor productivity growth seems to be approximately 2 percent. Before the Golden Age of 1950 to 1973, productivity grew at about a 2¼ percent annual rate between 1890 and 1929 and about a of 1 percent rate between 1929 and 1938. Even a 2 percent trend would be superior to the economy's performance during the 1970s and 1980s.

An important bottom line for me as a policymaker is that the state of the economic science of productivity growth contains many huge gaps. The state of knowledge does not justify firm convictions about any productivity growth forecast, although a range of 3 to 4 percent over the next few years does seem sensible to me.

Given our incomplete knowledge, it is important that we not lock ourselves into a monetary policy that depends on any particular rate of productivity growth. It is certainly quite possible that today's productivity growth will be maintained for the next decade, or rise further. By the same token, it is obviously dangerous to simply assume that our good times will roll on for the foreseeable future. It is not very satisfying for a former academic to say that we're going to have to watch carefully, and that such watching is about the best advice we can take. But that does seem to me to be our situation, like it or not.