

As Easy as P.I.E.: Productivity, Innovation, and Education

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How economies grow and prosper is one of the central questions of economics. At least since the time of Adam Smith, economists have recognized that enhancing living standards is as easy as P.I.E.: combine productivity, innovation, and education. Productivity growth is the critical factor that determines future living standards. Such growth, in turn, depends on the birth of new ideas—innovation and invention—and our ability to turn such ideas into usable technology—that is, technology transfer. Both, in turn, depend on education.

Speeding innovation through government assistance is not a new idea. In 1974, for example, the U.S. government's varied research laboratories joined together to form a consortium to promote technology transfer; in 1986 their efforts were codified into federal law by the Federal Technology Transfer Act. A number of new applicable technologies have resulted from this public-private liaison, including new tests to rapidly identify food contamination and new chemicals (spun off from the NASA space exploration program) to increase the cooling capacity of your automobile air conditioner. Numerous other examples are available on the consortium's Internet web site.

But, my topic tonight is not to speak of individual new technologies. Rather, I will discuss how economists—and especially policymakers—think of technology. In so doing, I am going to focus my remarks on productivity growth, a result of technology transfer.

Before proceeding, I want to emphasize that the views I express here are mine and do not nec-

essarily reflect official positions of the Federal Reserve System. I appreciate comments provided by my colleagues in the Research Division at the Federal Reserve Bank of St. Louis. Richard G. Anderson and Kevin L. Kliesen provided especially valuable assistance. However, I take full responsibility for errors.

OUR PRODUCTIVITY EXPERIENCE

Our economy is a dynamic, ever-changing system. As a result, productivity growth ebbs and flows, often for reasons only imperfectly understood. Yet, all economists appreciate that the interaction among productivity, innovation and education is crucial to maximizing economic growth.

There is now little doubt that the pace of productivity growth in the United States rose during the last decade. From 1995 to 2001, non-farm labor productivity grew at an annual rate of nearly 2.5 percent, more than a percentage point faster than the disappointing performance seen from 1973 to 1995. Increases in business efficiency boosted expectations of the future growth of corporate earnings. Increased efficiency also lowered unit labor costs and allowed steady increases in wages without triggering higher inflation. In turn, higher expected earnings fed into higher equity prices. Both the higher real earnings—earnings after adjustment for inflation—and increased wealth supported strong gains in the average household's standard of living. A higher standard of living is precisely what we desire from effective technology transfer.

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What caused these events of the 1990s? In the early 1990s, innovations in the production of microprocessors and related semi-conductors allowed sharp decreases in the prices of computing and telecommunications equipment. In turn, businesses aggressively reorganized their management information systems. In addition, other entrepreneurs quickly introduced machine tools, material-handling equipment, and similar capital goods that contained embedded microprocessors. Some economists have equated the importance of this technology transfer—that is, the successful combination of innovation and technology so as to improve productivity—with the introduction of the electric dynamo during the last part of the 19th century and the widespread adoption of scientific agriculture during the early 20th century.

Let me emphasize that the productivity improvement we're discussing required innovations in hardware, in software and in business processes. Any two of these without the third would have yielded disappointing results.

Wal-Mart Corporation is perhaps the most widely discussed example of how the adoption of lower-cost communications and information processing equipment can make possible fundamental changes in business management. Wal-Mart's information systems deliver data—hour-by-hour, product-by-product and store-by-store—both to management and to Wal-Mart's distribution centers. Such information systems are expensive, to be sure—but the benefits seem to have exceeded the costs. Last year, Wal-Mart became the nation's largest firm measured by annual sales. Yet, Wal-Mart's success did not depend just on innovations within the confines of that firm. Because Wal-Mart encouraged its suppliers to link to its information system, those suppliers have improved their information and inventory management systems. In turn, the suppliers of those firms have found it profitable, and often necessary, to improve their information and inventory management systems, and so on. Through this tiering process, Wal-Mart itself has become a powerful engine of technology transfer for the entire U.S. economy.

The close relationship between technology transfer and economic prosperity is a prominent

theme in economic history. Economic historians seem to agree that large gains in living standards do not arise from specific innovations or inventions but, rather, from the *application* of such innovations by those seeking to capitalize on them. The noted historian Angus Maddison has argued that 1820 marked a major turning point in economic history. About 1820, businesses began productive use of the innovations of the 18th century, including the steam engine, the railroad locomotive and chemical processes like bleaching. Ever since that time, the economy's ratio of capital to labor has tended to increase fairly steadily—and productivity along with it. As a consequence, in England and the United States output per capita began to double approximately every 40 to 50 years. Although modest-sounding by today's standards, this advance was truly remarkable: in total, during the previous millennium, worldwide real GDP per capita had increased only about 50 percent.

Productivity growth during the 20th century followed that of the 19th century—adoption of important innovations raised productivity growth. As a consequence, U.S. output per capita began to double about every 30 years. Not surprisingly, the annual growth rate of nonfarm business productivity slowed during the Depression, averaging approximately 1½ percent between 1929 and 1938. In the United States, the “Golden Age” seems to have been 1950 to 1973, when productivity increased at almost a 3 percent annual rate.

Around 1973, however, U.S. productivity growth began to stall. From 1973 to 1995, nonfarm labor productivity grew at a Depression-like 1.4 percent annual rate. As with many significant economic events, there doesn't seem to be a simple explanation for the decline. Nor was the productivity slowdown recognized immediately. By 1976, however, it was evident that something structurally significant had happened to the U.S. economy. In 1977, a full four to five years after the slowdown started, the Council of Economic Advisers, then headed by Alan Greenspan, trimmed its estimate of potential GDP growth from about 4 percent to 3.5 percent. But later events were to show that even that rate was much too optimistic.

What caused that productivity slowdown? The 1977 *Economic Report of the President* argued that the permanent increase in real energy prices following the Arab oil embargo likely was a significant factor. Other factors included higher inflation, a dramatic escalation in environmental and workplace regulations, and an influx of a large number of persons into the labor force for the first time, especially women and teenagers. Subsequent economic research has reached essentially the same conclusion. Interestingly, though, the oil shock story continues to be favored by many economists.

Overall, real per capita income in the United States has increased more than eight-fold during the last 200 years. The pace has been uneven, both in time and geography, but it has been remarkable nonetheless. Today, we can only hope that the roughly 2½ percent annual growth in U.S. labor productivity since 1995 continues. Even a 2 percent growth trend would be superior to the economy's dismal productivity performance during the 1970s and much of the 1980s.

BOOSTING PRODUCTIVITY THROUGH INNOVATION

According to official productivity data compiled by the Bureau of Labor Statistics (BLS), the post-1973 slowdown—that is, relative to the productivity surge that occurred from 1948 to 1973—was attributable entirely to a slowdown in the rate of technical progress, what economists call total factor productivity, or TFP.

To understand what TFP means, note that economists attribute output growth to three components: increases in labor input, growth in the nation's capital stock, which increases capital input, and everything else. We think of the catchall term “everything else” as reflecting advances in knowledge because this is the part of output in excess of what can be accounted for by measured inputs of labor and capital. No self-respecting discipline would ever name an important concept “everything else,” so in the productivity literature, this term is referred to as “total factor productivity.”

Economists use statistical models of the economy's production process to separate these three components. Measuring the first two components is difficult but relatively straightforward because firms report to the government each year both their employment and their capital purchases and depreciation. Measuring true innovation—changes in our knowledge of how to do things—is difficult. In fact, this extremely important component is typically measured as a residual—everything else—after accounting for other factors.

Despite this difficulty, there are many things that we *do* know about what fosters innovation—and what doesn't. Writing chiefly about information technology (IT), Stanford University economist Timothy Bresnahan has argued that IT innovations *by themselves* are of little value to the aggregate economy. He argues that another two key developments must also occur. First, the invention must be an “enabling technology.” That is, it must be one that can be used in numerous applications—these are the ones that eventually will boost growth. Second, the most valuable innovations are those with network effects, a type of economic externality. In other words, the value created by an IT innovation is related to the breadth of its use across the economy. But, these benefits may take a long time to appear.

A common example among economic historians is early 20th century electrification. Electrification enhanced productivity by increasing flexibility and allowing manufacturers to use labor and capital more efficiently. For example, electrification enabled use of continuous-process techniques such as the factory assembly line. Efficiency also improved with the widespread adoption of “unit drive,” that is, the use of relatively inexpensive, dedicated electric motors to power individual machines and tools, rather than using a system of shafts and belts powered by a single central engine. Unit drive brought savings through reduced energy usage, less wear and tear, and more flexible and efficient factory design. Electrification also enhanced productivity by improving factory lighting and safety.

But this process didn't occur overnight. Firms are reluctant to scrap old technologies, typically

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embodied in expensive plant and equipment, merely on the unproven promise of newer ones. Hence, these benefits are delayed by substantial adjustment costs related to reorganizing the way of doing business—what Bresnahan calls “co-invention” costs. Initially, early adopters prove that the new techniques work. Later, as wider adoption of these innovations creates some economy of scale in the production of the new equipment, the cost of the new technology decreases, providing a further incentive for firms to finally take the leap to the newer technologies.

Recognizing these trends seems easy with the benefit of hindsight. It is not hard to find the successes; the false starts and outright failures may never appear in the historical record. In practice, however, parsing current economic data does not readily yield clues to emerging trends that may be the result of past innovations. The most obvious example in recent years was the policy debate from about 1995 to 1998. On the one side were the so-called “New Economy” apostles, those who believed that innovations associated with the microchip had permanently increased the growth rate of labor productivity. According to this group, the economy’s potential growth had risen to approximately 3 to 3.5 percent—implying a long-run productivity growth rate of 2 to 2.5 percent (the remaining 1 percent growth attributable to labor force growth). Some New Economy advocates apparently had much higher growth rates in mind, although they typically did not commit to specific estimates. On the other side were the “traditionalists,” those who believed that real GDP growth was beginning to rise mainly because of cyclical dynamics (gradual re-employment of slack resources), or other temporary factors, and that once those benefits had been exhausted, the economy would be back to a longer run trend growth rate of about 2.5 percent, as had been experienced from 1973.

At the time, official data seemed squarely aligned with the traditionalists and mainstream forecasters. Despite persistently strong output growth, and hence persistently one-sided forecast errors, most forecasters projected a return to the old trend growth. Inside the Fed, or more accu-

rately, at the Board of Governors in Washington, D.C., Chairman Greenspan saw tantalizing evidence of a pickup in productivity growth that seemed simply inconsistent with what official data indicated. In his view, the linkages between reported data on profits, prices and costs did not add up the way economic theory suggested. The picture changed with subsequent revisions to the data—in particular, the incorporation of software as a fixed investment in the GDP accounts in 1999—and econometric work by several economists. This research showed that Chairman Greenspan’s intuition was essentially correct.

My point is not to rejoin that debate but rather to emphasize that the benefits of enabling technologies often evolve slowly, and the economic shifts that they cause may be difficult to recognize in the data. There is no easy way to distinguish new trends from temporary aberrations in existing trends. We should not, for example, dismiss the promise of e-commerce or business-to-business applications simply because they have yet to take off. I am not making a forecast one way or the other, but emphasizing that history suggests ample reason to be cautious in both directions.

BOOSTING PRODUCTIVITY THROUGH EDUCATION

So far, I have focused on technology. But, how do innovation and technology transfer occur? And, can governments do anything to encourage more rapid technological progress and economic growth? During the industrial revolutions of the 18th and 19th centuries, for example, private individuals and firms produced most inventions and did “technology transfer” largely without government subsidies or direction. Although economists are far from having a complete understanding of these issues, economic analysis provides some guidance.

First, government should “do no harm.” Excessive regulation and rigidity can stifle the transformation of innovations into applicable technology. Many analysts have noted that few

other countries enjoyed a rise of productivity growth during the 1990s as rapid as did the United States. In part, the explanation for such a difference may lie in the relatively less-regulated, more flexible, and more competitive nature of U.S. markets and business. The United States does a good job of encouraging entrepreneurs.

Encouraging entrepreneurs seems simple until we consider that new technology creates losers along with winners. The transfer of new technologies—such as growing use of the steam engine, electricity, the internal combustion engine, and the microchip—changes the relative fortunes of numerous firms and, in turn, the relative demand for various types of labor. As a result, wages of some workers will tend to increase rapidly—while earnings and jobs in other industries will contract. Government leaders must resist the urge to “save” the latter industries lest, by so doing, they foreclose gains for the overall economy.

While no one likes to observe layoffs and business closings, these may signal the future direction of the economy. Government must be cautious not to interfere with these signals. It is particularly damaging when governments protect existing jobs by stifling innovation and blocking entry of new products, services and producers.

Second, government must provide a secure system of private property rights, including protection for intellectual capital. Douglass North, the noted Washington University economic historian and Nobel laureate, has argued that a nation’s institutions, including its government, are among the most fundamental determinants of economic growth. Economic performance tends to be better, he argues, when government intervention in private markets is minimal except for the enforcement of private property rights. Secure property rights, including clear ownership of intellectual property via patents and copyrights, encourage entrepreneurship and technology transfer.

Third, government must sponsor a strong and widely available system of higher education. Economist Paul Romer, a leading growth expert at Stanford University, has argued that “...the real success of American economic policy has been to have moderately strong property rights

with lots of subsidies for inputs—like research and education—that are used in the innovation process.”

Many economic historians credit the U.S. higher education system for our technological prowess. The Morrill Act of 1862 created land grant universities, thereby stimulating teaching and research in both agriculture and engineering. Within a decade after the Act’s passage, the number of engineering schools went from 6 to 70, and later to 126 schools by 1917. In 1870, U.S. engineering schools graduated 100 students; in 1917, they graduated 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. As late as 1914 the United States was well behind Europe in scientific agriculture. A generation later, we were the world leader. Today, our higher education system is called upon to provide the new talent to maintain our technology leadership. Over the last 25 years or so, the college wage premium—the wages of college graduates relative to those of high school graduates—has jumped 25 percent. A little more than a decade ago, about 39 percent of the population 25 years and older had some form of college education; in 2000, the proportion had risen to 50 percent. Technological progress—turning innovations into applicable technology—simultaneously depends on a well-educated labor force and increases the demand for higher education.

IMPLICATIONS FOR MONETARY POLICY

Finally, I come to my fourth thought of the evening: the government, and more specifically, the Federal Reserve, must follow sound macro-economic policies consistent with a low, stable rate of inflation.

The strength and duration of the current economic expansion will ultimately depend on the performance of the inflation rate. Low and stable inflation reduces uncertainty regarding the future health of the economy and, in turn, encourages

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entrepreneurship and risk-taking. High and variable inflation increases risk, which induces caution among entrepreneurs and venture capitalists. The consequence is less innovation and less application of known innovations.

Monetary policymaking requires an estimate of the potential growth rate of the economy because it gives us a sense of how fast the economy can grow without developing inflationary imbalances. Growth more rapid than the long-run path can generate imbalances that threaten long-run sustained prosperity. Yet, no policymaker wants to unnecessarily slow a booming economy if the economy's performance reflects an acceleration of productivity. Productivity increases are the largest part of our economy's long-run growth. Even the recent, mild economic slowdown seems to have done little to slow productivity's acceleration that started in the mid 1990s. Recent data are highly encouraging; fourth-quarter productivity growth was more than 5 percent, and first quarter growth could even be as high as a remarkable 8 percent. As a result, unit labor costs have decreased, corporate profits have increased, and business investment spending is rebounding.

Many analysts now believe that the economy's sustainable productivity growth rate is approximately 2 to 2½ percent. A modestly higher rate

cannot be ruled out. Accepting the forecast of 2 to 2½ percent trend productivity growth, then the economy's long-run growth track, assuming that the labor force increases approximately 1 percent each year, is approximately 3 to 3.5 percent, about a percentage point higher than the track that prevailed between 1973 and 1995. Maintaining the higher track will raise the living standards of future generations of Americans, as well as those in countries we trade with. But this outcome can only come to pass so long as inflation remains low and stable.

Yet, we must be modest. Our understanding of the determinants of productivity growth is too imprecise to justify firm convictions about any productivity growth forecast over the near term, much less the long run. Given our incomplete knowledge, therefore, it is important that we not lock ourselves into a monetary policy that depends on any particular rate of productivity growth. Instead, policymakers must be on guard that an increase in inflation does not derail the economy's long-run growth combination of innovation, productivity and education.

I'll finish with this observation: it is a lot easier—a whole lot easier—to be a policymaker in an environment of strong productivity growth than in one of stagnation.