PRODUCTIVITY POSTPONED

The late 20th century witnessed huge leaps in information technology innovation, but gains in productivity were slow to follow. Economists, including two with ties to the Richmond Fed, help explain why

BY VANESSA SUMO

Almost every company has a story to tell about how the power of information technology, or IT, has transformed its business. Dell, the world's largest personal computer manufacturer, takes orders directly from customers via the Internet, builds computers exactly to their specifications, and ships, all within 24 hours. Wal-Mart's Retail Link system shares actual sales, forecasts, and inventory data from its 6,200 stores with 30,000 suppliers worldwide, which allows the company to respond effectively to customer demand and minimize inventory costs. On-board computers enable dispatchers and truck drivers to communicate, and thus make decisions that keep big rigs fully loaded and on the road.

An improvement in productivity, or the ability to produce more goods and services for the same amount of effort, generates higher profits for the company and its owners and wages for its workers, and therefore a better standard of living over time. Technological progress is key to productivity growth because it offers a better way of doing things, of pushing out an economy's frontier of production possibilities. Sometimes this progress is subtle — for instance, when marginal improvements are made to existing technologies — while in other cases, it is stark. History counts several examples of major innovations. The steam engine, electricity, and the internal combustion engine are just some of the creations that have raised living standards over the centuries.

Similarly, many believe that the advancements in IT, triggered by the invention of the microchip, have ushered in a period of fast productivity growth in America. "Technological innovation, and in particular the spread of information technology, has revolutionized the conduct of business over the past decade and resulted in rising rates of productivity growth," remarked former Federal Reserve Bank Chairman Alan Greenspan in December 2000. Average labor productivity, or the amount of output produced for each hour worked, grew by 2.6 percent a year for the nonfarm business sector between 1995 and 2004, double the pace between 1973 and 1995, according to data from the Bureau of Labor Statistics.

Labor productivity depends partly on the amount of capital each worker is equipped with — the more machines per worker, the higher his productivity. But labor productivity also depends on something called "total factor productivity," or TFP, a term which measures the growth in output that is not due to changes in either capital or labor. TFP is usually associated with technological change because it tries to capture the efficiency with which labor and capital inputs are used. For instance, TFP rose by 1.3 percent per year from 1995 to 2004, accounting for half of the overall growth in labor productivity. And like the growth in labor productivity, TFP has increased much faster than in the two previous decades.

But it was not always so evident that IT could be a driving force for productivity growth. A period of weak productivity gains in the two decades to the mid-1990s spurred many economists, including Andreas Hornstein of the Richmond Fed and Per Krusell of Princeton University (and also a Richmond Fed visiting scholar) to attempt to explain this period. They find that after rising by 1.9 percent a year from 1954 to 1973, labor productivity actually reversed to -0.2 percent a year from 1973 to 1979 before recovering to positive territory of 1.1 percent a year from 1979 to 1993 (although still trailing the pre-1973 pace).

Changes in TFP were similar. This was puzzling in the wake of widespread introduction of robotics and microprocessor technologies. Why hadn't these innovations boosted productivity? One could not blame Nobel laureate economist Robert Solow when he famously observed in 1987, "You can see the computer age everywhere but in the productivity statistics."

Dissecting the Slowdown

Perhaps a good way to understand this productivity paradox is to reach even further back in history. The invention of the dynamo (the electrical generator) and the course of electrification that followed beginning in 1880 had promised profound transformations to every factory, store, and home. But the realization of such a vision was hardly imminent at the turn of the 20th century, according to Stanford University economist Paul David.

Aside from the slow pace of electrification and the durability of the old manufacturing "group drive" system of power transmission, machines had to be fitted with electric motors (which meant that old machines and new ones operated alongside one another), factory structures had to be radically redesigned, and the stock of factory architects, electrical engineers, and workers familiar with the new machines needed to be built up. This protracted adjustment made gains in productivity slow to come.

Similarly in the 1970s, computer technology did not manifest itself immediately in a revolutionary way, and maybe this isn't surprising. Some research shows that the transition to a new technological regime can actually slow productivity growth as firms take time to learn how to use the new technology. This period of "learning-by-doing" is one of the more intriguing explanations, proposed by Hornstein and Krusell, for the slowdown of measured TFP growth during the two decades to the mid-1990s.

"The idea is that new machines require an investment in learning that is not measured. Since a rise in unmeasured investment spending leads to an underestimated output growth, measured TFP growth is lower," explains Hornstein. "Another way of looking at it is that if we assign the same experience level across all equipment, including the new ones, then we will tend to overestimate the contribution of the new capital equipment to output growth, hence underestimating observable productivity growth."

This problem arises if new technologies embodied in the latest equipment are introduced at a rapid pace, forcing workers to learn faster on the job. The 1970s offers a neat example. Faster and better computers flooded the market every year, such that the quality-adjusted price of their components (processor speed, memory, etc.) dropped dramatically. Hornstein and Krusell find that prior to 1973, the price of producers' durable equipment was falling by 2.9 percent a year, whereas after 1973 it was falling by an additional 0.6 percentage point per year. The cheaper prices encouraged firms to accumulate more and more IT capital.

But in a world where a new machine cannot simply be plugged and played, the adoption of a new technology can temporarily reduce a worker's productivity simply because the effective use of the new equipment is initially overestimated. The evidence suggests this is what happened in the 1970s. As the pace of capital-embodied technical change quickens, TFP growth will initially be lower because only a fraction of the new equipment is actually operable. Firms need time to learn how to best integrate the new technology in their production plans and workers need to update their skills. As this adjustment moves forward, the process of learning-by-doing will bring in additional productivity gains.

Other studies have treaded along similar lines as those of Hornstein and Krusell; that is, the idea that there is some delay in reaping the benefits of investments in IT. Economists Susanto Basu of Boston College, John Fernald of the San Francisco Fed, Nicholas Oulton of the London School of Economics, and Sylaja Srinivasan of the Bank of England find that in order to benefit from IT, there must be "substantial investments in learning, reorganization, and the like, so that the payoff in terms of measured output may be long delayed."

This study follows naturally from where Hornstein and Krusell left off. Although TFP growth is initially underestimated because such investments are not measured, it is actually overestimated once these complementary investments become an increasingly important part of the production process. Indeed, the authors find that the surge in measured TFP growth in the late 1990s in the United States is positively correlated with high IT capital growth rates in the 1980s or early 1990s, but negatively correlated with the growth rate of IT investment in the same period.

These investments are in intangible assets such as new organizational designs, worker knowledge, and monitoring and incentive systems. Although intangible, these assets are not invisible and so would likely show up in the market's estimation of a firm's value. No wonder that when Johnson & Johnson finally discovered its winning formula for combining computer-based flexible machinery with a carefully designed work plan for manufacturing adhesive bandages, it ordered its factory windows painted black to prevent competitors from running away with its valuable blueprint.

Measured productivity growth can also understate actual improvements in

The use of personal computers became widespread in the 1980s, but may have done little to boost workers' productivity until years later.

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productivity, according to Hornstein and Krusell, if the quality component of a final good or service is very high. For instance, simply comparing the number of cars produced today to 20 years ago does not reflect the significant quality changes that a typical car has undergone. It would be more appropriate to adjust a good or service for its quality content, but that is often difficult to do.

In addition, this understatement is exacerbated the more capital-intensive the production of the quality component of output is relative to quantity. Computers, for example, are a big part of how banks are able to offer customers increasingly convenient ways of transacting. In that case, a large portion of the increase in the capital stock actually reduces TFP growth because the output growth that it generates goes unmeasured. Hence, measured improvements in TFP can slow during a period of rapid technological change because IT capital goods are factored into the equation — but the quality and convenience of these new services eludes output statistics.

The late economist Zvi Griliches emphasized the consequences of poor measurement for the "unmeasurable sectors" of the economy, mostly the services industries. He showed that despite heavy investments made in computers and other information-processing equipment, more than three-quarters of this investment went into the unmeasurable sectors, thus its productivity effects were largely invisible in the data.

To make matters worse, the structure of the economy has changed significantly whereas data improvements have come slowly. The share of the services sector in total output, for instance, has increased substantially over the past half-century, weighing in today at about three-quarters of GDP.

The services sector is singled out by Hornstein and Krusell, as well as others, as the most problematic in this respect, because innovations from these industries are trickier to identify than the new products that come from the goods sector. Until a few years ago, bank output was measured by extrapolating from the number of bank employees, which surely would not capture the convenience and time-saving benefits from the rise of ATM networks.

Much has changed, however. Because of new and improved ways of measuring services output in the U.S. industry data, recent estimates by economists Jack Triplett and Barry Bosworth of the Brookings Institution were able to uncover the robust growth in productivity that had always been there after all. Using the new data, they find that the services sector no longer lagged behind the goods industries in terms of productivity growth. Labor productivity in services increased by 2.6 percent a year between 1995 and 2001, outpacing the 2.3 percent a year improvement in labor productivity in the goods sector.

Still, unlike Hornstein and Krusell, Triplett does not believe that measurement errors are the reason for the slowdown in productivity growth during the 1970s and 1980s. "That's still a big puzzle," says Triplett. "I suspect that it was a lot of different things like the oil shock, regulation, baby boomers entering labor force." Each of those may have had a small effect, but taken together, the result was significant.

Another view of the productivity slowdown offered by Northwestern University economist Robert Gordon, in a comment to Hornstein and Krusell's paper, is that the slowdown in productivity growth may be partly due to the "new economy" of IT simply falling short of some of the remarkable inventions of the past. It just did not have the potential to spur a massive acceleration in TFP. "The one big wave of American economic growth during 1915 to 1965," writes Gordon, "reflects the combined influence of several central inventions that, taken together, had a much more profound impact on the way the economy and society operated than has the electronic computer."

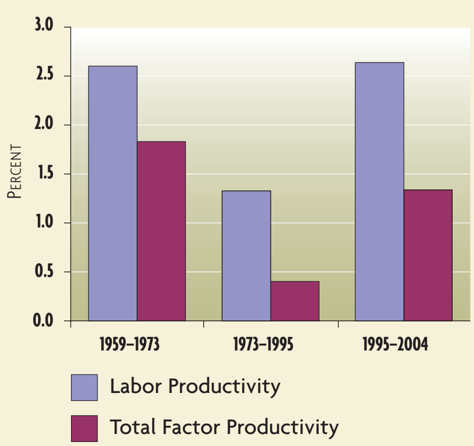
The Revival

After a long dismal period in the two decades to 1995, productivity growth began to surge to heights that would be expected of an economy booming with IT-stimulated innovations and investments. Dale Jorgenson and Mun Ho of Harvard University and New York Fed economist Kevin Stiroh find that average labor productivity grew by 2.64 percent a year over the period 1995 to 2004 compared with 1.39 percent from 1973 to 1995, representing a gain of 1.25 percent a year. Of this difference, 0.62 percent a year was due to capital deepening (the increase in the amount of equipment used per worker) and 0.72 percent was due to faster TFP growth.

The remarkable contribution of technological progress in IT production is reflected in the 30 percent share of the IT-producing sector to the increase in TFP growth over the two periods, contributing far more than the 3.9 percent share of IT equipment and software in aggregate output. This impressive productivity performance

Labor Productivity and Total Factor Productivity Growth

Despite the growing use of computers, productivity growth slowed between 1973 and 1995 but finally surged between 1995 and 2004.



NOTES: Labor productivity growth is the average annual percentage change in output per hour for workers in the nonfarm business sector. The growth in labor productivity partly depends on total factor productivity growth, which is the average annual percentage change in output that is not accounted for by changes in either capital or labor. Average annual growth rates are computed using a geometric average.

SOURCE: Bureau of Labor Statistics

has played an important role in the fall in IT prices and thus in boosting IT investment. This has led to the wide diffusion of IT capital across all sectors, reflected in the two-thirds share of capital deepening attributed to IT.

But one thorny issue is whether these gains have actually spilled over to industries outside of the IT-producing sector. The services sector comes to mind since these industries are heavy users of IT capital, but some also believe they have been afflicted with "Baumol's Disease" — a theory developed by New York University economist William Baumol which supposes that the inherent nature of services causes them to languish in terms of productivity improvements.

Triplett and Bosworth, who were among the first to look at productivity growth in the services sector, discover evidence to the contrary. They find that most of the acceleration in labor productivity growth after 1995, and all of the acceleration in TFP growth, took place in the services industries. This lays to rest previous assertions that the productivity growth of the 1990s was fragile because no improvements in productivity, particularly TFP, occurred outside the electronics manufacturing sector. Moreover, they find that four-fifths of the total contribution of IT to aggregate labor productivity growth between 1995 and 2001 is thanks to the services industries.

Strong productivity growth continued after the late 1990s, even beyond the end of the 1991 to 2000 expansion. This has led to the consensus that the resurgence was not cyclical, that it would not fade away even as output growth slowed down. Rather, it represents something more sustainable, suggesting that the American economy could continue to expand, raising standards of living.

Will this strong productivity growth continue? "It depends on what the innovations are going to be and in what ways we can expand the variety of products in an economy," Hornstein says. "I think there is still some potential there, for the application of IT and for productivity growth." Jorgenson, Ho, and Stiroh anchor their projections critically on factors such as the evolution of semiconductor technology and business investment patterns. Nevertheless, they find "little evidence to suggest that the technology-led productivity resurgence is over or that the U.S. economy will revert to the slower pace of productivity growth of the 1970s and 1980s."

Gordon likewise predicts that productivity growth rates will stay firm, similar to the growth rate of the late '90s, but doubts that IT will be the main driving force. "I tend to think we have now exploited the low-hanging fruit of the Internet revolution," says Gordon. Electricity and the internal combustion engine were mega-inventions, in terms of their direct effects and the importance of their spin-offs and complements. On the other hand, he considers the semiconductor, computer chip, and digitalization merely "first-rate" inventions that likewise spawned other first-rate inventions, particularly the Internet. Beyond that, he sees only a slew of second-rate innovations, a string of bit-by-bit technical improvements instead of the revolution that we enjoyed during the last decade.

A look back shows that IT has had a profound impact on productivity growth, even during periods when this bond may not have seemed so strong. But there is less of a consensus about the role of IT in propelling productivity growth in the future, in part because some puzzles still remain. One lingering question is why IT did not spur a similar productivity revival in Europe when, after all, a computer is the same anywhere in the world. The tumultuous affair between technology and productivity looks certain to continue. **RF**

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