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U.S. ECONOMY
technology
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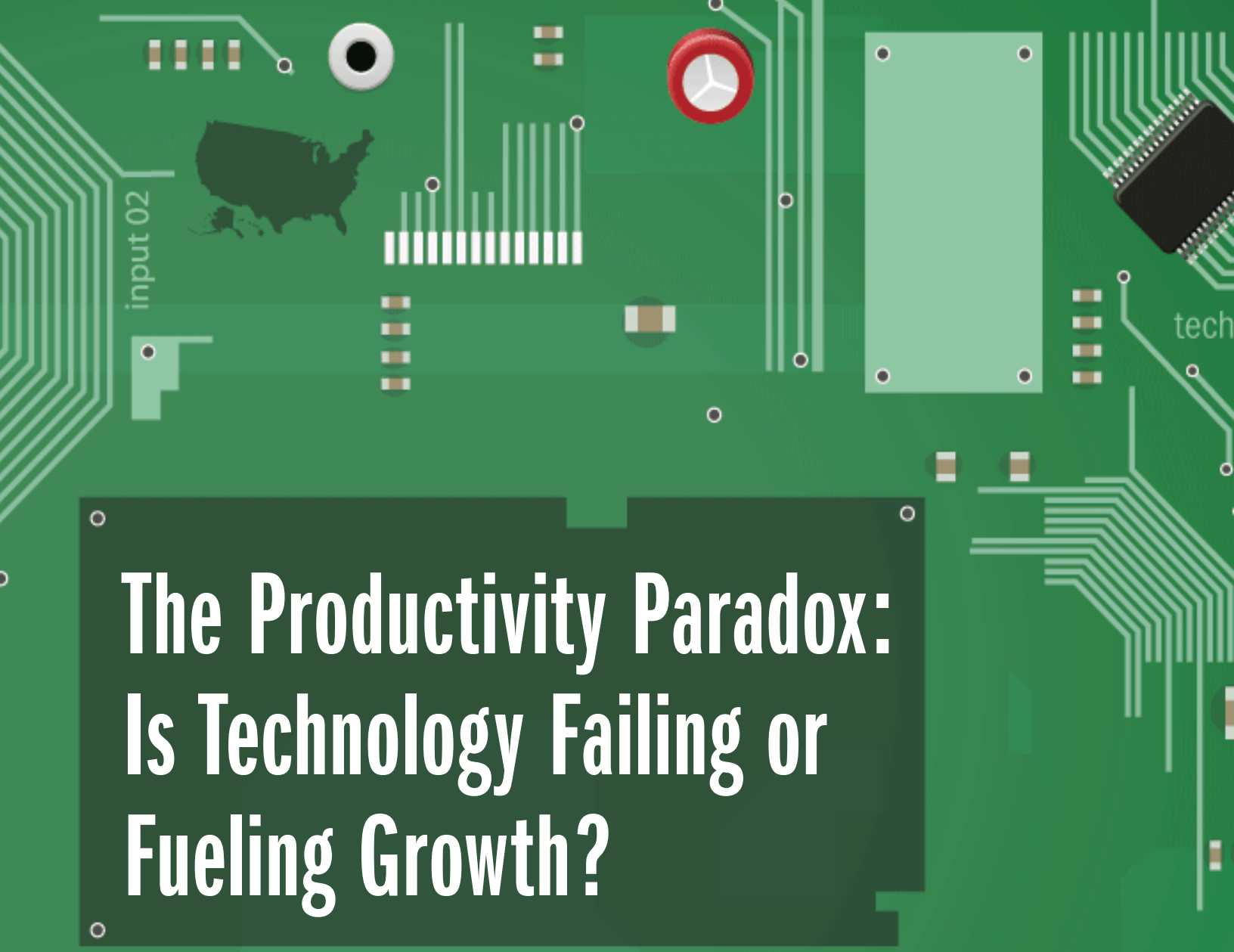


The Productivity Paradox: Is Technology Failing or Fueling Growth?

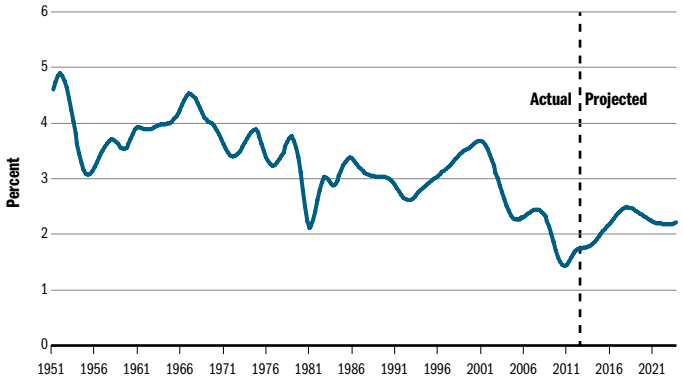
Nobel Prize-winning economist Robert Solow famously said, "You can see the computer age everywhere but in the productivity statistics." Is the economy in technological stagnation? Or will computers take all our jobs?

The U.S. economy has grown slowly since the recession ended in 2009, more slowly than in past recovery periods. The depth of the recession, and the financial crisis that exacerbated it, surely explain this sluggishness—right? Not according to some economists, who think we have a bigger problem on our hands: that the underlying dynamics of the economy are impaired and our ability to innovate new technologies is the root cause of the current stagnation. In other words, they argue, slow growth is the new normal. But other economists take the opposite stance. These economists say that technology is improving so rapidly that machine intelligence and automation will replace much of human labor. And while overall growth will improve, technology is bound to radically reshape our economy, making it more unequal. Which story is correct? Let's look at some evidence found in long-run trends.

Cyclical versus structural trends

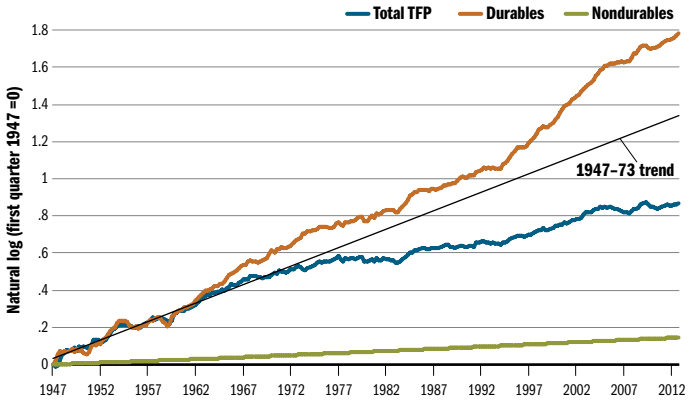
Economists tend to analyze changes in economic growth in two ways: cyclical and structural. Cyclical trends refer to a shorter horizon and pertain to the business cycle—or the nature of the economy to periodically experience expansions and recessions, booms and busts. Structural trends, however,

Chart 1
Potential GDP: Percent Change from Previous Year



Source: U.S. Congressional Budget Office

Chart 2
U.S. Total Factor Productivity (TFP)



Source: John Fernald, "A Quarterly, Utilization-Adjusted Series on Total Factor Productivity," Working Paper 2012-19, Federal Reserve Bank of San Francisco, September 2012

pertain to the underlying dynamics of the economy and are observable only over a longer time period. Such trends include changes in demographics and the diffusion of new technologies, for example. The Federal Reserve, in setting monetary policy, mostly focuses on cyclical trends, but structural changes can dramatically affect how monetary policy should be implemented and how well it can help the economy.

A structural slowdown in economic growth does not mean just a slowing of real gross domestic product (GDP). It also means a slowing of potential GDP, which estimates the amount of real GDP that corresponds to a high rate of use of labor and capital resources. The Congressional Budget Office (CBO) estimates that three factors largely explain the slowing of potential GDP growth in recent years (see chart 1): potential employment, net new investment, and total factor productivity (TFP).

Much of the slowdown in potential GDP is due to changing demographics—specifically, the aging and retirement of the baby boomer generation. The sagging of net investment, which is investment minus depreciation, has also lowered the U.S. economy's growth ceiling. But it's the third factor—productivity—that has the attention of economists examining long-run growth prospects. However you slice the data, it seems the U.S. economy has experienced a slowdown in productivity growth.

Productivity and technology

Productivity growth, in the long run, largely drives economic growth. It can also boost potential employment and spur greater investment. There are two widely cited measures of productivity: labor productivity and total factor productivity.

The first measure is technically defined as the inflation-adjusted output per hour worked. TFP, on the other hand, incorporates multiple factors, including both labor and capital. It is sometimes called multifactor productivity. It's calculated as a residual from total output and the factor inputs. Although we measure TFP indirectly, it is the variable that best captures what economists mean by productivity for the economy as a whole. In fact, it was Robert Solow's pathbreaking research on economic growth that effectively created the concept of TFP. In growth models, this variable is often called "technology." When economists examine structural trends in potential GDP, TFP is their preferred measure of productivity. The CBO, the Federal Reserve, and other policymakers use this measure when projecting long-run economic growth (see chart 2).

Looking at the data on both U.S. labor productivity and TFP shows why some economists are worried. Though labor productivity and TFP are highly cyclical measures, they also exhibit long-term trends—and the growth in both series has been slowing for several decades. This decline is a major reason for the falling potential GDP. John Fernald, an economist with the Federal Reserve Bank of San Francisco, has constructed a utilization-adjusted TFP series for the United States, which shows a downshift in TFP growth in the early 1970s. But the story gets more interesting when we separate TFP into durables and nondurables. Productivity growth in the creation of durable goods has soared in the past several decades but has been stagnant in nondurables.

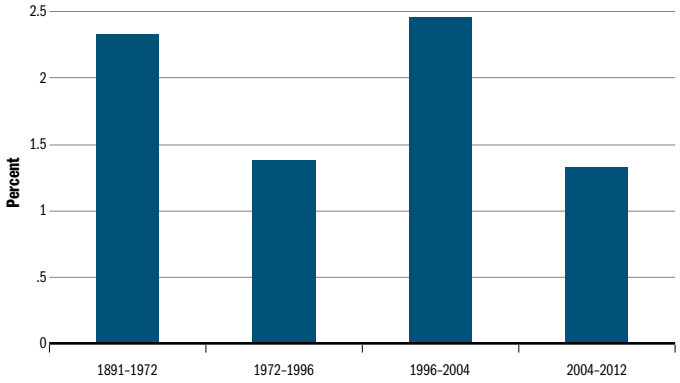
Some economists have used these trends as a launch point into "techno-pessimism."

The good old days

Techno-pessimists argue that technological innovation is nothing like what it used to be. In his provocative 2012 paper, "Is

Chart 3

Average Growth Rates of U.S. Labor Productivity over Selected Intervals, 1891–2012



Source: Robert Gordon, "Is U.S. Economic Growth Over?," National Bureau of Economic Research Working Paper 18315, August 2012, nber.org/papers/w18315

U.S. Economic Growth Over?," macroeconomist Robert Gordon argues that "economic growth may not be a continuous long-run process that lasts forever."

In the paper, Gordon classified U.S. economic history into three industrial revolutions (IR). The first IR (1750–1830) was powered by steam and railroads. The second IR (1870–1900) was sparked by electricity, the internal combustion engine, transportation, communications (telephone and television), running water, and many other innovations. The third IR (1960 to the present) is the computer revolution brought on by microprocessors, the Internet, and mobile phones. Gordon claims that this third IR has been disappointing in terms of productivity. Except for a brief period, from about 1996 to 2004, the computer revolution did not materially boost productivity growth.

Gordon created a chart (see chart 3) to show the decline in U.S. labor productivity—which is different than TFP in only measuring worker efficiency—during different historical periods. This chart shows that the greatest gains in productivity came about with the second IR, though with a time lag. Innovations in transportation, in communications and entertainment, and in the home and workplace all had lasting effects, driving high productivity increases that continued through the post–World War II period.

Gordon outlines six headwinds to today's economic growth: unfavorable demographics (the aging and retirement of the baby boomers), a plateau in educational attainment, rising economic inequality, globalization-driven outsourcing to inexpensive foreign labor, energy price increases and environmental regulations, and, finally, large household and government debt levels. Combining these headwinds, Gordon foresees per capita growth for most Americans falling from the norm of 2 percent to below 1 percent. In his view, we won't be getting any poorer, but we will be growing a lot more slowly because the best technological innovations have already been made.

Some might protest that the remarkable advances in technology that we've seen in recent years—such as smartphones, the testing of driverless cars, and advances in machine learning—would belie the view that our ability to innovate is in a structural slowdown. This seeming confusion between the remarkable advances in technology around us and declining productivity statistics has even been dubbed the "productivity paradox."

Techno-optimism

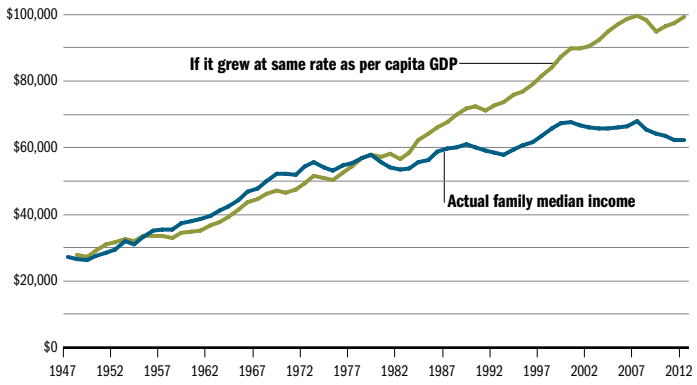
But are we really not innovating? Some say the economy is poised for bursts of innovation in the years to come. In 2011, Erik Brynjolfsson and Andrew McAfee from MIT wrote a provocative book about technology and its economic impact. In *Race Against the Machine: How the Digital Revolution Is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy*, the authors cover a litany of the latest innovations—like IBM's supercomputer

Watson, which won a $1 million pot on *Jeopardy*—suggesting that innovation is alive and well.

Brynjolfsson and McAfee make use of Gordon's analysis to explain the first two industrial revolutions: it takes time for newly created technologies to mature and develop commercial applications. It took decades from the invention of electricity until its widespread deployment in our infrastructure. Why wouldn't the same be true for semiconductors and the Internet? Brynjolfsson and McAfee think it is too soon to say the computer age has disappointed us.

Brynjolfsson and McAfee believe that the labor market recovery has been weak not because innovation has slowed,

Chart 4
Inflation-Adjusted Family Median Income



Source: Tyler Cowen, *The Great Stagnation*, Penguin Group: London, 2011

but because innovation has developed so fast it has displaced workers. In other words, the link between value creation and job creation—an assumption of classical economic thinking—is more tenuous because the underlying structure of the economy has changed.

Further pushback to the techno-pessimists' story comes from Joel Mokyr, an economic historian at Northwestern. In a recent op-ed at VoxEu.org, Mokyr argued that propositional knowledge (basic science, for example) leads to prescriptive knowledge (like scientific applications), and that more time is needed to let this feedback loop work itself out for the computer age. Mokyr asks, "How would we ever have discovered the structure of DNA without X-ray crystallography?" Science progresses with better tools, which are then used to make even better tools, which then lead to better science. And so the cycle of innovation continues. Mokyr is optimistic that the cycle will continue, as computers and the Internet have provided better access to information than ever before.

A mix of both

Another view of productivity and innovation incorporates ideas of both techno-pessimists and techno-optimists. People who hold this view agree with Gordon's claim that recent decades have seen a technological plateau, but they also argue that future technological advances in machine intelligence will bring about accelerated, if highly unequal, growth. This blended view is best expressed in the recent writings of Tyler Cowen, an economist at George Mason University who writes the popular blog *Marginal Revolution* (marginalrevolution.com).

Regarding recent decades, Cowen is a techno-pessimist, albeit with a slightly different argument than Gordon's. In his 2011 book, *The Great Stagnation*, Cowen argues that land, technology, and education have already been exploited for growth, so later improvements on the margin will have less of an impact. Like Gordon, Cowen singles out the 1880–1940 period as one that produced numerous advances in our standard of living. But since 1973, after these innovations ran their course, median family income growth has slowed significantly (see chart 4). (Median family income growth is Cowen's preferred measure to reflect the stagnation.)

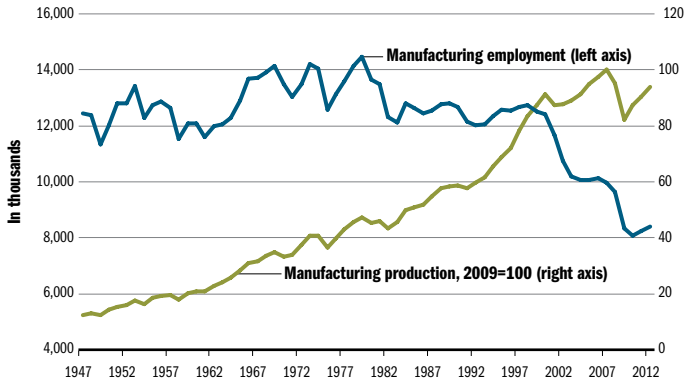
Cowen adds nuance to this story. He points out that because many online products are free, standard economics statistics do not capture them. Thus, according to Cowen, "innovation hasn't ceased, but it has taken new forms and it has come in areas we did not predict very well." But this idea leads to larger questions: Do current economic statistics—created in an age of industrialized production, with clear value-added measures—fully capture how technology is contributing to the economy? And is there a growing disconnect between economic statistics purported to measure our standard of living and our actual well-being?

In fall 2013, Cowen released another book, *Average Is Over: Powering America beyond the Age of the Great*

Stagnation, which extrapolates recent technological trends to paint a highly meritocratic and unequal economic picture. In Cowen's view, machine intelligence—advances in artificial intelligence, better industrial automation, the proliferation of smartphones, and more—will create a class of very well-off workers, with skills complementary to machines. This view is similar to what Brynjolfsson and McAfee express in *Race Against the Machine*. In Cowen's vision of the future, a significant minority of the labor force—he speculates 15 percent—will have a standard of living equivalent to today's million-

Chart 5

Manufacturing: Total Employment and Production



Sources: Federal Reserve Board of Governors, U.S. Bureau of Labor Statistics

aires. The rest will experience stagnant income growth and dire job prospects, given the rise of machine intelligence in displacing workers with incompatible skills. Cowen is not advocating this future, merely putting forth analysis of current trends.

Labor market implications

Considering these competing views on productivity and technology, we come to the most salient economic issue of our time: jobs. The rate of technological innovation obviously has major labor market effects. What is the relationship between new technological advances and the current skill distribution of the labor force?

Skill-biased technical change is the economic theory for how advances in technology can increase worker productivity, given compatible skills, but how they also displace certain workers. Think of the automation improvements in U.S. manufacturing. Total inflation-adjusted manufacturing production has never been higher than it is now, and manufacturing productivity, if anything, increased following World War II. But the total number of persons employed in manufacturing industries fell sharply, even more so as a percentage of the labor force (see chart 5). Driving these trends have been advances in machinery, supply chain management, and automation, among other efficiency improvements.

Cowen and the authors of *Race Against the Machine* foresee skill-biased technical change as accelerating in the future. They see the fruits of this third industrial revolution—information technology—as having just begun to disrupt the labor market. This view is augmented by the recent research of David Autor, an MIT economist, who highlights a slightly different, and perhaps more disturbing, phenomenon: *labor market polarization*. Autor and his coauthors document the rise in demand for both high- and low-skill occupations alongside a decline in demand for middle-skill workers. They then tie technological automation to this erosion of middle-skill occupations. Manufacturing is one big area where these middle-skill jobs exist.

Low-skill jobs, like home health aides, janitors, and fast-food workers, tend to be classified in the domestic nontradable sector. In other words, these jobs are in service industries and the labor cannot be outsourced. At the other end, the high-skill jobs are increasingly defined by computer-compatible skills.

If the techno-optimists are correct about the future, the combination of skill-biased technical change and greater labor market polarization will complicate the already serious state of the U.S. labor market.

But is it mostly cyclical?

To put all this in perspective: the techno-pessimists and techno-optimists are likely outnumbered by the mainstream view, held by most economists and policymakers. Atlanta Fed President Dennis Lockhart expressed the mainstream view in a 2013 speech titled "Is the U.S. Economy Losing Its Dynamism?":

> I have assumed we are experiencing a temporary spell of low productivity growth that will correct itself. I am assuming this will happen as demand kicks into higher gear and as businesses expand production somewhat faster than they expand their payrolls.

In other words, the recent low productivity readings and the weak labor market are primarily symptoms of an economy slowly recovering from the greatest recession and financial crisis since the Great Depression. In this view, technological innovation has not plateaued or become permanently depressed, nor are we on the precipice of massive labor-displacing technological revolution.

Economic growth in the long run will be driven by productivity increases, and thus by technology. The debate between techno-pessimists and techno-optimists is not going away, and it could not be more relevant to our future standard of living. ▮

This article was written by Andrew Flowers, a senior economic research analyst in the Atlanta Fed's research department.