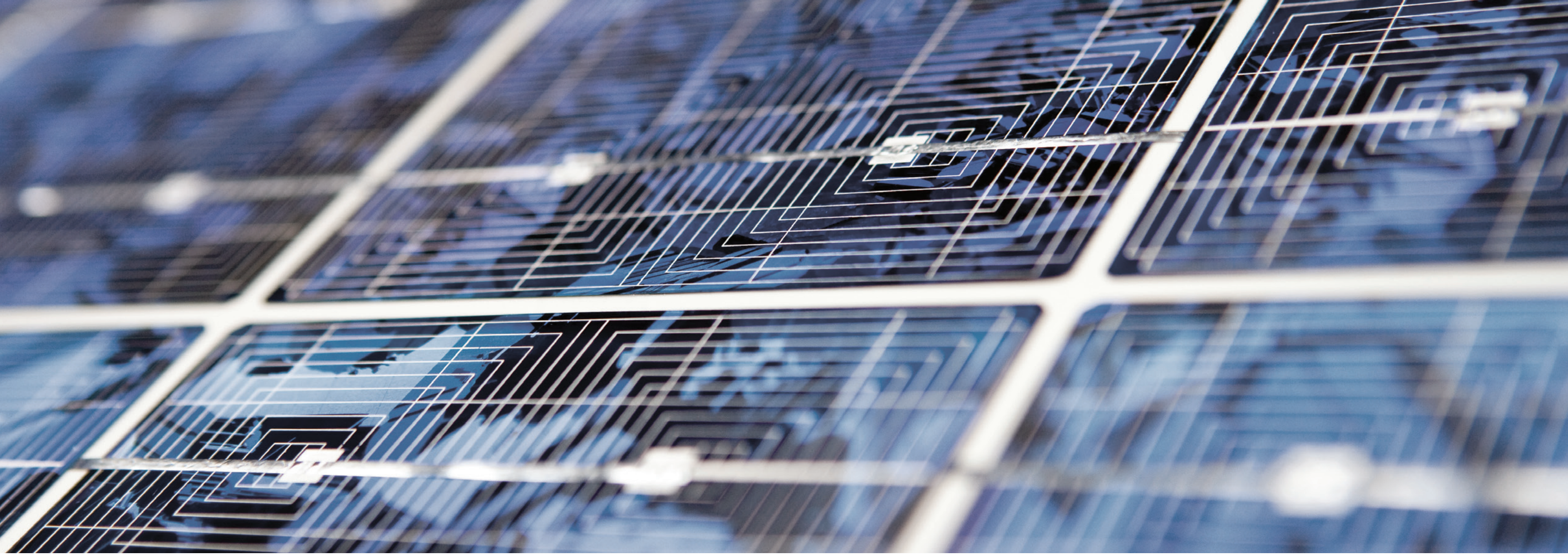

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When will Technological Progress Show Up in Productivity Statistics?

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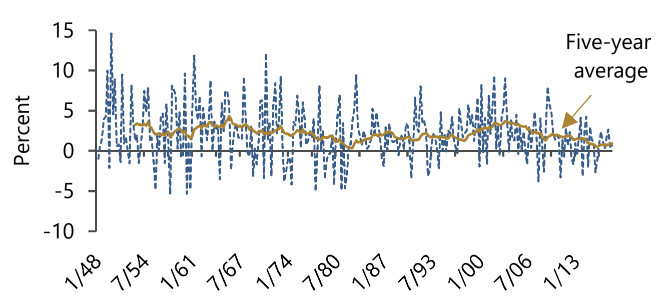
The key call in any macroeconomic forecast is judging how fast the real output of an economy will grow over the longer term. Trend growth, or the expansion rate of potential output, has three parts: the pace of the increase in population, their participation in the workforce, and the growth rate of output per hour worked. The first two components are about demographics, and demographics is mostly preordained in forecasting since its forces typically evolve slowly.

The third part, output per hour or productivity, is more challenging.[1] As seen in the first chart, the quarter-to-quarter gyrations of productivity growth in the United State are considerable. In fact, in about 1980, economists belatedly identified markedly slower US productivity growth starting in 1973. As a result, there was a nearly decade worth of mistakes at the Federal Reserve, when policymakers thought that the economy had more room to run than was actually the case.

The solid line smooths through the quarterly changes in output per hour by taking a five-year moving average, which shows the low frequency or trend movements. Herein lies the bad news about the economic outlook: the growth of productivity has slowed significantly, starting from a local peak around 2003, so that potential real GDP accordingly tracks along a reduced path.

Output per Hour in Nonfarm Businesses Quarterly Growth



Source: Bureau of Economic Analysis, accessed via FRED.

Any economic forecast, including ours, gravitates toward that pole. Despite ongoing financial accommodation and significant fiscal impetus, US real GDP growth is only in the upper 2 percent range in 2018 and falls back next year. Even so, this tepid performance of aggregate demand, by historical standards, imparts pressure on resources and costs.

[1] Chad Syverson of the University of Chicago's Booth School presented an overview of these issues at the Federal Reserve Bank of Atlanta's recent annual financial markets conference, found here: https://www.frbatlanta.org/-/media/documents/news/conferences/2018/0506-financial-markets-conference/papers/syverson-chad-ai-productivity-paradox-for-distribution.pdf.

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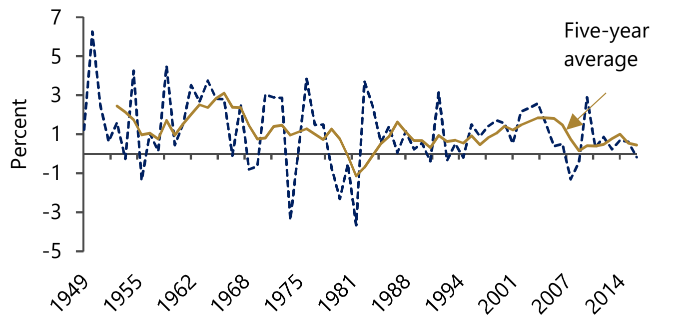
Productivity growth has slowed even after controlling for the amount and quality of inputs in production. What is left, multifactor productivity, grows slowly. This should be disturbing because another name for multifactor productivity is technological progress—the portion of extra output that comes without adding extra inputs.

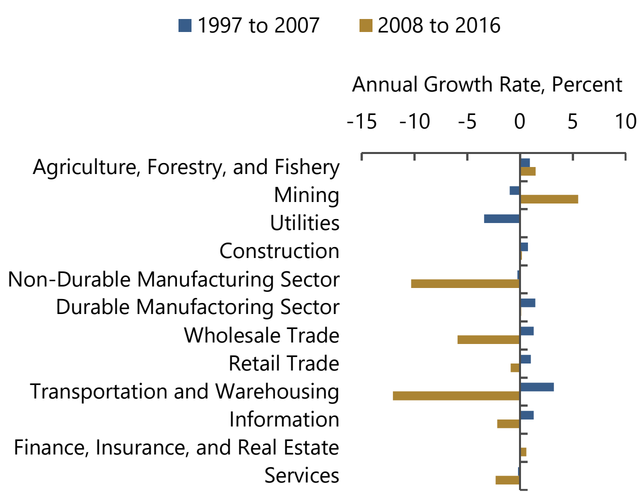
Multifactor Productivity in Nonfarm Businesses Quarterly Growth



Source: Bureau of Economic Analysis, accessed via FRED.

We can track this measure of technological progress across major industries. For most of them, the pace of progress has stalled when comparing the experience from 1997 to 2007 with 2008 to 2016.

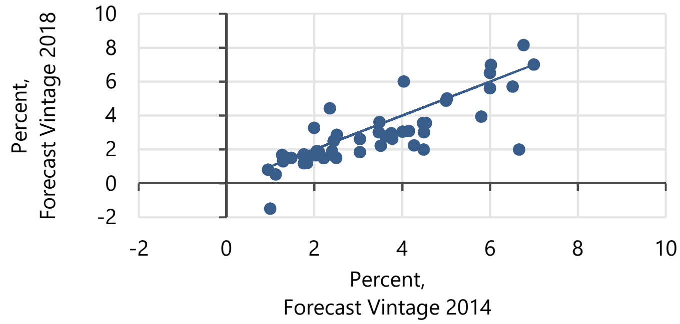
Multifactor Productivity



Source: Bureau of Economic Analysis.

This is not unique to the United States. The next chart looks at long-term trend real GDP growth as assessed by staff at the International Monetary Fund in their semiannual *World Economic Outlook* for the fifty largest economies of the world, which covers 94 percent of global GDP. The Fund staff's forecast for trend growth in 2014 is plotted along the horizontal axis and their new take in April 2018 on that same measure is along the vertical axis. Most pairs are below the 45-degree axis, showing markdowns in long-term trend in two-out-of-three cases.

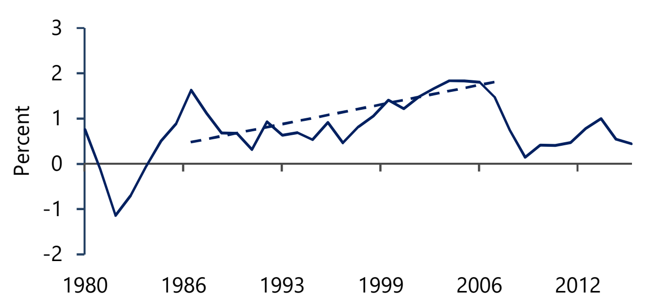
Long-term Trend Real GDP Growth for the Fifty Largest Economies



Source: International Monetary Fund, World Economic Outlook (2014 and 2018).

This sounds wrong. Driverless cars, genetic engineering, 3D printing, big data stored in the cloud, and fast chips making machine learning practicable seem likely to invigorate productivity. The divergence of interest and output is so extreme as to repeat the "Solow Paradox." Famously in 1987, the economist Robert Solow said, "You can see the computer age everywhere but in the productivity statistics."[2] After the fact, this could be called the Solow Mistake, as shown by the next chart, which repeats the five-year average growth of multi-factor productivity over a more concise span. As Solow was offering his paradox, the as-yet reported data was embarking on a significant ten-year expansion. Faster multifactor productivity growth implied a quicker expansion of labor productivity and, commensurately, of potential output. This is the macroeconomic change, by the way, that Alan Greenspan detected first among policy makers, which became the stuff of legend.[3]

Multifactor Productivity in Nonfarm Businesses Five-year Average Annual Growth



Source: Bureau of Economic Analysis, accessed via FRED.

If this is really a new Solow Paradox, mismeasurement may be the explanation. The answer to the question "Are economic data mismeasured?" is always "Yes." Official reports are approximations, derived from small samples, of a large, rapidly moving economy. But why would output per hour be mismeasured across industries, after controlling for inputs, and around the world? While measuring the quality of output is hard, the official sector does better job measuring nominal sales, mostly to collect taxes. If there really is more output out there, the price level must be much lower and have increased much less over the past decade. Which seems less improbable—slow productivity growth or unmeasured price deflation?

[2] Solow, Robert M. 1987. "We'd better watch out", *New York Times Book Review (July 12)*: 36.
[3] This is part of the reason Sebastian Mallaby titled his biography, *The Man Who Knew*, Penguin Press 2016.

The Solow Paradox may be in play because of a different mistake—primarily thinking that the latest wave of technical innovation will reap outsized benefits. Perhaps the reason it is difficult to detect direct output gains from these technologies, other than providing more of what is mostly given away, is that they do not exist. After all, investors were giddy about using diving bells to recover lost treasure in the late 17th century. The oceans turned out to be big, and the technology lacking. Big data might be about finding drops in a different ocean with similar success.

The third possibility, which I emphasize here, is that we are impatient, and anyone venturing that productivity has stalled over the long run is repeating the Solow Mistake, not the Solow Paradox. Technological progress of late mostly falls into the class of general purpose technologies that can be used across many industries and in many different kinds of applications.

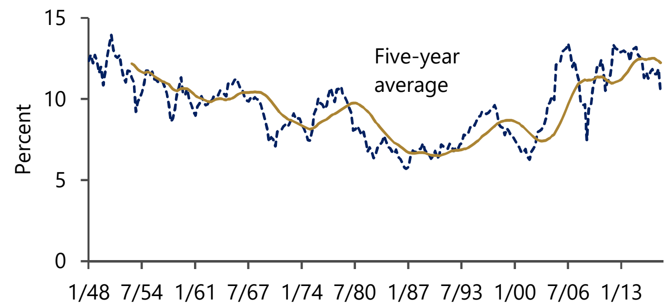
The most famous general purpose technology in human history is the wheel. The wheel, as Archimedes explained, is a lever moving continuously along a surface. Undoubtedly, this overwhelming gain in efficiency took time to put in practice. Transporting objects with a wheel displaced an industry carrying burdens on workers and animals' backs (reducing the value of sunk capital investment) and, at the same time, required new capital to literally harness the technology to pull rather than carry. This was not just about more capital to build more wheels; specific innovation was needed to place the wheel efficiently in a transport mechanism, from wheelbarrow to cart to chariot. Plus, the roads had to be wider and smoother. At the beginning, our greatest technological innovation probably lowered output as it displaced former capital and required investment into projects with long lead times. Over time, as applications flourished, the wheel added to output per hour work. However, its contribution did not really take off until it was fully adopted. Roads were eventually safer because of increased traffic and the delivery coverage widened with way stations to transfer from a tired donkey to a fresh one. This defines a network externality.

This pattern of the negative, slow, and suddenly substantial contributions of a general purpose technology was repeated with water, steam and electric (or portable) power and traces out a sideways "S."[4] As David discusses, widespread industrial use of electric power only took hold in the early 1920s, about forty years after Edison's first large-scale generator stations. We saw it with the computer, witness the Solow Mistake.

Perhaps the application of machine learning and the cloud to modern business is our current challenge. In the same way that too many firms put down fiber optic cable in the 1990s, too many firms might be pursuing driverless cars. Why did they do it in both instances?

Another feature of general purpose technologies is that winners often garner large rewards as users gravitate to their products because other users are already there. The same network externalities that spur productivity also lend themselves to concentration in industry. That might be why corporate profits relative to GDP moves steadily higher.

Corporate Profits (with Inventory Valuation Adjustments) Relative to GDP



Source: Bureau of Economic Analysis, accessed via FRED.

As for a bottom line, a general purpose technology disrupts existing business structures, requires time to design and build specific applications, and becomes more useful when its application is widespread. It may also be associated with increased concentration.

Therefore, we can be a productivity optimist, expecting better performance over the next decade or so, but also predict more concentration. The biggest challenge about the S-curve is predicting when it inflects up. It has not yet appeared in the data, and my pedestrian forecast for the next two years is anchored by that reality. For a ten-year forecast, I suspect that too many productivity pessimists abound. This might be already reflected in the valuation of the firms that will benefit from general purpose technologies. The problem remains, even if productivity takes off, the distinct winners and losers will only be settled over time.

[4] This is covered most famously in Paul A. David, "The dynamo and the computer: an historical perspective on the modern productivity paradox." *The American Economic Review* 80.2 (1990): 355-361.

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