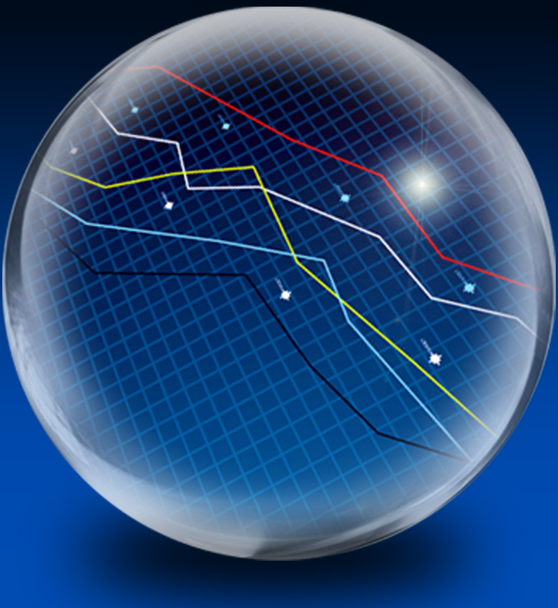
UNDERSTANDING THE GROWTH SLOWDOWN



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Understanding the Growth Slowdown

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Editor's Introduction

Brink Lindsey[1]

When asked what he thought the stock market would do, J. P. Morgan famously replied, "It will fluctuate." The same can be said of economic growth. Indeed, the variability of the process is perhaps its most obvious feature. The expansions and contractions of the business cycle provide the headline-grabbing drama of modern economic life: companies and industries rise and fall, fortunes are made and lost, jobs are created and destroyed by the millions, all in rhythm with the years-long inhalations and exhalations of aggregate supply and demand. But beneath the surface of boom and bust, a deeper and ultimately more consequential drama unfolds: the long-term, secular growth of output and incomes, most frequently measured these days in terms of real (i.e., inflation-adjusted) gross domestic product (GDP) per capita. Shifts in the rate of long-term growth are often apparent only years after they have occurred, but they are as momentous as they are subtle. Yes, the swings of the pendulum attract most of the attention, but what matters more is how the whole clock is moving.

In the wake of the Great Recession of 2007–9 and the stubbornly sluggish recovery that has ensued, there is gathering evidence that one of these profound shifts in the slope of the long-term growth trend is now under way. In other words, the disappointing performance of the U.S. economy in recent years—the slowest postrecession expansion since World War II—may not be just a temporary setback after an especially severe downturn. Rather, slow growth for the indefinite future could be the "new normal."

The purpose of the present volume is to investigate whether that is indeed the case—and, if so, why. This book had its origins in a Cato Institute conference in December 2014 on the future of U.S.

[1] Brink Lindsey is vice president for research at the Cato Institute. He thanks Chelsea German for invaluable research assistance in editing this volume.

economic growth.[2] The nine chapters collected herein consist of papers (or, in two cases, reprints of previously published works) submitted by participants in the first three of the day's five panels.[3] The names of those panels provide the titles for this book's three sections: "Forecasting the Long-Term Growth Outlook," "The Future of Innovation," and "Is Economic Dynamism in Decline?" Each section contains three chapters authored or coauthored by the participants in the relevant conference panel.

Section One offers an assessment of the U.S. economy's long-term growth prospects. Of crucial significance to any such inquiry is an evaluation of the likely future course of so-called total factor productivity (TFP) growth—the growth in output per unit of labor and capital. TFP growth is economists' best measure of the pace of aggregate output-enhancing innovation, which is the ultimate source of long-term growth.

In Chapter 1, Dale Jorgenson, Mun Ho, and Jon Samuels provide a detailed breakdown of TFP growth since World War II at the level of 65 specific industries. The story they tell of shifts in aggregate productivity growth is a familiar one: rapid gains in the quarter century after World War II, a prolonged slump from the early 1970s to the mid-1990s, an Internet-fueled resurgence from the mid-1990s to the mid-2000s, and a resumption of slow growth since then. What leaps out of their industry-level analysis is a much less widely appreciated phenomenon—namely, the highly imbalanced nature of productivity growth since the early 1970s. Specifically, productivity growth in recent decades has been highly concentrated in the comparatively tiny sector of information technology (IT)–producing industries. Comprising only 2.5 percent of total output over the whole postwar period, IT-producing industries have accounted for the bulk of overall TFP growth since the productivity slowdown of the 1970s. Accordingly, a significant contributing factor behind the more recent TFP slowdown is the offshoring of much of IT production since 2000.

[2] "The Future of U.S. Economic Growth," December 4, 2014, Cato Institute, Washington, D.C., http://www.cato.org/events/future-us-economic-growth. This conference, the present volume, and the ebook referred to in footnote 3, were all made possible by the generous support of the Searle Freedom Trust, the Ewing Marion Kauffman Foundation, and the Carthage Foundation.

[3] Essays submitted by speakers at the conference's final two panels and other participants in a special online forum have been published as a separate ebook. See Brink Lindsey, ed., *Reviving Economic Growth* (Washington, D.C.: Cato Institute, 2015).

Looking ahead, Jorgenson, Ho, and Samuels project that growth in potential real aggregate GDP during 2012–22 will range between 1.56 percent and 2.20 percent a year, with a baseline projection of 1.75 percent a year. When adjusted for population growth during this period, their baseline projection comes to only about 1.0 percent a year. By comparison, the long-term average growth of real U.S. GDP per capita from 1870 to 2010 was 1.96 percent a year. Accordingly, Jorgenson and his coauthors are expecting growth over the next decade to slow to only about half its historical pace.

In Chapter 2, John Fernald and coauthors Bing Wang and Mark Juneau offer a somewhat more optimistic analysis. They project long-term growth in real aggregate GDP of 2.1 percent a year—which translates into per capita GDP growth of about 1.4 percent a year. In other words, Fernald and colleagues foresee a drop-off in the U.S. growth rate of about 30 percent compared to its long-term historical record. Critical to this analysis is Fernald and his coauthors' finding—in line with Jorgenson and his coauthors—that productivity growth slowed down prior to the Great Recession. Of course, measured productivity growth was affected by the steep cyclical downturn of the recession (during slumps, capacity utilization typically falls faster than employment, causing output per hour to drop well below its potential), but Fernald has developed techniques to adjust productivity-growth estimates to account for variations in utilization. In any event, those variations had ceased affecting productivity growth in any material way by 2012 or 2013. The slower path of productivity growth over the past decade, Fernald and coauthors therefore conclude, must have its origins in structural rather than cyclical factors.

In Chapter 3, Martin Baily and Barry Bosworth agree that the sluggish recovery from the Great Recession is primarily for structural reasons. They then examine three possible explanations. First, they consider the possibility that the recession has had a permanent negative effect on aggregate supply—for example, by causing discouraged workers to drop out of the workforce. They conclude, in keeping with analysis by the Congressional Budget Office, that most of the downward revision in long-term growth prospects that has occurred in recent years reflects a reassessment of excessively optimistic expectations rather than lingering effects of the recession. Next, they examine whether the slowdown in productivity growth identified by Jorgenson, Fernald, and their coauthors is due to a corresponding slowdown in technological change—or whether it might be simply an artifact of measurement problems. Here, Baily and Bosworth hedge their bets: they acknowledge the possibility that IT's acceleration of TFP growth was fleeting and is now over, but they are also open to the idea that worsening measurement problems, particularly those associated with the globalization of production chains, are masking the true pace of innovation.

Finally and most intriguingly, Baily and Bosworth look at whether the nature of U.S. innovation has changed. Specifically, they speculate that the old dual-economy model of economic development pioneered by Arthur Lewis may now be operating in reverse. In Lewis's model, less developed economies feature a modern sector and a traditional subsistence sector dominated by agriculture, with a deep pool of excess labor. As the modern sector expands, it pulls away excess labor from the subsistence sector, strengthening productivity performance across the board. By contrast, in the United States, beginning in the 1960s and 1970s, the "modern" dynamic sector's rising demand for labor began to slow, and an increasing percentage of the workforce was shunted into low-productivity sectors. The result is downward pressure on both productivity growth and wages.

Section Two addresses the provocative claim that the growth slowdown reflects the gradual exhaustion of technological progress. The leading proponent of this viewpoint is Robert Gordon, the author of Chapter 4. In a series of papers, Gordon has argued that the contemporary revolution in IT, however impressive, simply does not compare to the clusters of transformative innovations that emerged in the late 19th and early 20th centuries. This assessment is summarized in the pointed question, summarized approximately here, that he likes to pose in speeches: "Would you rather have indoor plumbing or a smartphone?" And looking forward, Gordon is dubious that new technologies now in the pipeline—robots, artificial intelligence, 3-D printing, driverless cars—are capable of triggering a major productivity resurgence.

In Chapter 4, which was previously published elsewhere,[4] Gordon extends his analysis to make a broader case for growth pessimism. Assessing the outlook for the next 25 to 40 years, he assumes that

[4] Coen Teulings and Richard Baldwin, eds., *Secular Stagnation: Facts, Causes and Cures* (London: Centre for Economic Policy Research, 2014), pp. 41–59.

productivity growth will continue as it has over the past few decades. Accordingly, his take on the future potential for technological progress is bearish only relative to claims that progress will soon accelerate rapidly: he concedes that new innovations will suffice to maintain current rates of productivity growth but argues that there is no indication that a speedup is in the works. Meanwhile, he points to other "headwinds" that will work to reduce the growth rate for output and incomes: declining labor-force participation because of aging; the exhaustion of gains in worker skills from rising educational attainment; income inequality, which ensures that the aggregate growth rate does not translate into commensurate income gains for most workers; and rising government indebtedness.

In sharp contrast to Gordon, Erik Brynjolfsson is well known for his sunny assessment of information technology's future potential. Indeed, he and Gordon have been frequent sparring partners at live debates, including at the December 2014 Cato conference. In Chapter 5, which is excerpted from their book *The Second Machine Age*,[5] Brynjolfsson and Andrew McAfee make the case for techno-optimism. They note the slowdown in productivity growth over the past decade, but in their view it is just a "lull" before another big wave of progress. Further, they argue that much of the bounty from rising machine intelligence comes in the form of freebies (Google, Skype, Facebook, etc.) that never show up in GDP statistics.

Stepping back from the sharply diverging big-picture assessments of Gordon and Brynjolfsson, Stephen Oliner homes in on recent developments in the semiconductor industry to ground his own views about the likely future course of innovation. That industry, the subject of Gordon Moore's famous "law," has provided the foundation of the larger IT revolution; accordingly, if progress looks to be slackening there, that has much broader implications for the pace of IT advances generally. In Chapter 6, Oliner finds that technological progress in semiconductor manufacturing accelerated during the late 1990s and has subsequently slowed. Nevertheless, the cycle for doubling the number of components on a single chip remains shorter than it was back in the 1990s. Moore's law, Oliner concludes, is still going strong. He also contends that, notwithstanding the official

[5] Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* (New York: W. W. Norton, 2014).

statistics, the performance-adjusted price of semiconductors is still plummeting. While warning that predicting the future of productivity growth accurately is all but impossible, Oliner does find that "the underlying conditions needed for a second wave of the IT revolution are in place."

Section Three of the book examines another possible reason for the current economic malaise. Here the problem isn't a shortage of good new ideas—but, rather, a decline in the economic dynamism that translates good new ideas into actual new products and new companies. John Haltiwanger, together with a number of different coauthors, has played a critical role in bringing this concern to widespread attention. In a series of papers, Haltiwanger and his colleagues have documented a host of troubling trends—most notably, long-term declines in the rates of new-business formation and gross job creation and destruction. Although these trends may have had benign explanations in the past (in particular, the rise of national big-box retail chains that displaced small-scale mom-and-pop firms), since 2000 the trends are also apparent in the tech sector and among publicly traded companies. These data raise the troubling possibility that the intensity of "creative destruction" in the U.S. economy is ebbing—and, with it, the prospects for robust innovation and growth.

In Chapter 7, Haltiwanger reviews the evidence of declining dynamism and offers some possible explanations. In Chapter 8, Amar Bhidé presents other lines of evidence that suggest the environment for entrepreneurship and innovation remains favorable. Meanwhile, he offers a strong dissent from the prevailing view that productivity growth is our best overall measure of innovation; he believes that the methodological problems associated with calculating productivity are so severe that the resulting numbers are basically useless. Nevertheless, Bhidé admits that the data presented by Haltiwanger and coauthors are genuinely troubling.

In Chapter 9, Alex Tabarrok and Nathan Goldschlag recognize that the data on declining dynamism raise legitimate concerns and may indeed portend a deteriorating climate for innovation and growth. Interestingly, though, their analysis suggests that increased regulation is not the culprit. Furthermore, they remain open to more benign interpretations of the data. In particular, they note that larger firms and lower rates of self-employment are strongly associated with higher GDP per capita. In addition, using the recent turnaround of Ford Motor Company as an example, they point out that a great deal of entrepreneurship and innovation occurs within large firms. And they observe that (as in the retail sector recently) a move toward larger, more stable firms can be a sign of increased innovation and efficiency.

Readers who make their way through this entire volume will not be rewarded with clear, simple answers about what's behind the recent growth slowdown. On the contrary, they should emerge with more questions than answers. This is as it should be. The U.S. economy is a phenomenon of mind-boggling complexity; furthermore, its ongoing development is a one-off event without any historical precedent. Here at the frontier of technology, knowledge, and experience, every day is a further plunge into the unknown. Accordingly, when attempting to come to an overall assessment of the U.S. economy's future prospects, the only certainty is this: anybody peddling clear, simple answers doesn't know what he's talking about.

Since certainty is not an option, the best we can do is sift through the available evidence with the best analytical tools at our disposal. This is a gradual, deliberate, painstaking process, and its payoff rarely comes in dramatic epiphanies of incontestable clarity. But it is the only reliable pathway toward improved understanding. My hope is that the collected contributions to this volume offer a model of this process in action.

SECTION ONE

FORECASTING THE LONG-TERM GROWTH OUTLOOK

1. The Outlook for U.S. Economic Growth

Dale W. Jorgenson, Mun Ho, and Jon Samuels[1]

Introduction

In this chapter, we assess the outlook for U.S. economic growth for the period 2012–22. We begin by noting that economic growth can take place without innovation, through replication of established technologies. Investment increases the availability of these technologies, while the labor force expands as population grows. With only replication and without innovation, output will increase in proportion to capital and labor inputs. By contrast, the successful introduction of new products and new or altered processes, organization structures, systems, and business models generates growth of output that exceeds the growth of capital and labor inputs. This results in growth in productivity or output per unit of inputs. Productivity growth is the key economic indicator of innovation.[2]

We show that the great preponderance of U.S. economic growth since 1947 involves the replication of existing technologies through investment in equipment and software and expansion of the labor force. Contrary to the well-known views of Robert Solow (1957) and Simon Kuznets (1971), innovation accounts for only 20 percent of U.S. economic growth. This is the most important empirical finding from the extensive recent research on productivity measurement summarized by Jorgenson (2009).

[1] Dale W. Jorgenson is a professor of economics at Harvard University, Mun Ho is a visiting fellow at Resources for the Future, and Jon Samuels is with the U.S. Bureau of Economic Analysis. The views expressed in this paper are solely those of the authors and not necessarily those of the U.S. Bureau of Economic Analysis or the U.S. Department of Commerce.

[2] Sometimes the term "productivity" refers to output per worker or per hour worked. We use the term "labor productivity" to refer to this concept. Otherwise "productivity" refers to "total factor productivity" or output per unit of all inputs.

Despite the modest role of innovation in U.S. economic growth, the outlook for the U.S. economy depends critically on the performance of a relatively small number of sectors where the preponderance of innovation occurs. Accordingly, the focus of productivity measurement has shifted from the economy as a whole to individual industries, especially those involved in the production and use of information technology (IT). Paul Schreyer's Organization for Economic Cooperation and Development (2001) manual *Measuring Productivity* has established international standards for economy-wide and industry-level productivity measurement.

In this chapter, we introduce a new data set on the growth of U.S. output and productivity by industry for 1947–2012. This includes the 65 industries represented in the U.S. national accounts and incorporates output for each industry as well as inputs of capital (K), labor (L), energy (E), materials (M), and services (S). Productivity is the ratio of output to inputs. These data comprise a prototype industry-level production account within the framework of the U.S. National Income and Product Accounts. Our methodology for productivity measurement is consistent with the OECD standards.

We aggregate industries by means of the production possibility frontier employed by Jorgenson, Ho, and Stiroh (2005) and Jorgenson and Schreyer (2013). This methodology provides a link between industry-level data and macroeconomic data such as those reported by Michael Harper, Brent Moulton, Steven Rosenthal, and David Wasshausen (2009).[3] Our data for individual industries could also be linked to firm-level data to incorporate differences in productivity levels among businesses, which are the subject of the microeconomic research reviewed by Chad Syverson (2011).

We illustrate the application of the prototype industry-level production account by analyzing data for the postwar United States for three broad periods. These are the Postwar Recovery (1947–73), the Long Slump after the 1973 energy crisis (1973–95), and the period of Growth and Recession (1995–2012). To provide more detail on the period of Growth and Recession, we consider the subperiods 1995–2000, 2000–2007, and 2007–12—the Investment Boom, the Jobless Recovery, and the Great Recession, respectively.

[3] The most recent data set is available at http://www.bea.gov/national/integrated_prod.htm.

Finally, we consider the outlook for future U.S. economic growth. For this purpose, we have adapted the methodology for projecting economic growth originated by Jorgenson, Ho, and Stiroh (2008) and employed for recent projections of economic growth for the United States and the world economy by Jorgenson and Khuong Vu (2013). We utilize historical data on the sources of U.S. economic growth at the industry level, and we aggregate over industries to compare the results with projections summarized by David Byrne, Steven Oliner, and Daniel Sichel (2013).

Sources of U.S. Economic Growth

An industry-level production account within the framework of the U.S. national accounts is presented by Susan Fleck, Steven Rosenthal, Matthew Russell, Erich H. Strassner, and Lisa Usher (2014). This covers the period 1998–2010 for the 65 industrial sectors used in the U.S. National Income and Product Accounts. The capital and labor inputs are provided by the Bureau of Labor Statistics (BLS), while output and intermediate inputs are generated by the Bureau of Economic Analysis (BEA).[4] Labor-input estimates incorporate an earlier version of our data set.

The North American Industry Classification System (NAICS) includes the industries identified by Jorgenson, Ho, and Samuels (2014) as IT-producing industries—namely, computers and electronic products and two IT-services industries (information and data processing, and computer-systems design). Jorgenson, Ho, and Samuels (2014) have classified industries as IT using if the intensity of IT capital input is greater than the median for all U.S. industries that do not produce IT equipment, software, and services. We classify all other industries as non-IT.

Value added in the IT-producing industries from 1947 to 2012 constitutes only 2.5 percent of the U.S. economy, while the corresponding figure for the IT-using industries is 47.5 percent and the non-IT industries account for the remaining 50 percent. The IT-using industries are mainly in trade and services, and most manufacturing industries are in the non-IT sector. The NAICS provides much

[4] For current data, see http://www.bea.gov/. The BEA's data on output and intermediated inputs for 1998–2012 are included in our prototype industry-level production account for 1947–2012.

more detail on services and trade, especially the industries that are intensive users of IT. We begin by discussing the results for the IT-producing sectors, now defined to include the two IT-service sectors.

Figure 1.1 reveals a steady increase in the share of IT-producing industries in the growth of value added since 1947. This is paralleled by a decline in the contribution of non-IT industries, while the share of IT-using industries has remained relatively constant through 1995. Figure 1.2 decomposes the growth of value added for the period 1995–2012. The contributions of the IT-producing and IT-using industries peaked during the Investment Boom of 1995–2000 and have declined since then. The contribution of the non-IT industries also declined substantially.

Figure 1.3 gives the contributions to value added for the 65 individual industries over the period 1947–2012. In order to assess the relative importance of productivity growth at the industry level as a source of U.S. economic growth, we utilize the production possibility frontier of Jorgenson (1966). This approach gives the relationship between aggregate productivity growth and productivity growth at the industry level. The growth rate of aggregate productivity includes a weighted average of industry productivity growth rates.

Figure 1.1
CONTRIBUTIONS OF INDUSTRY GROUPS TO
VALUE ADDED GROWTH, 1947–2012

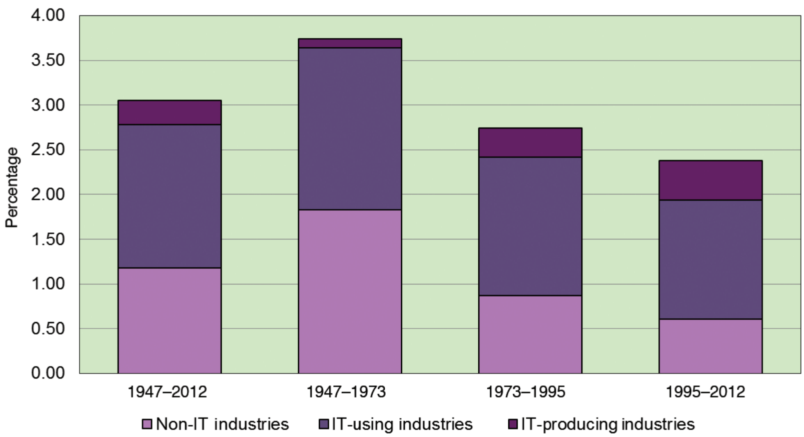
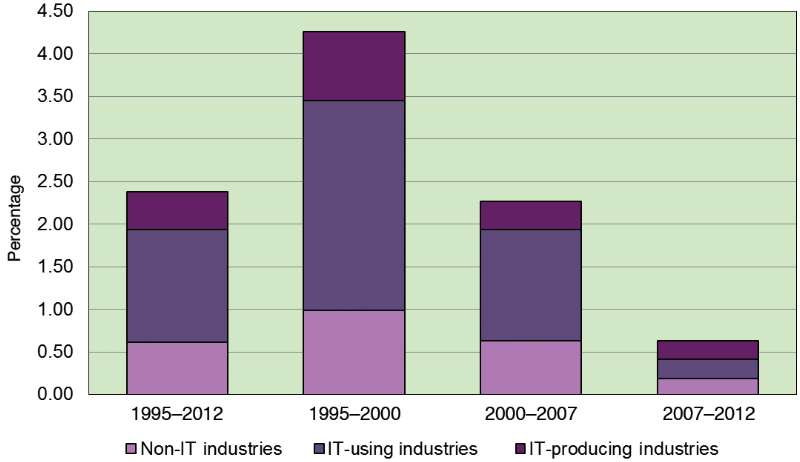


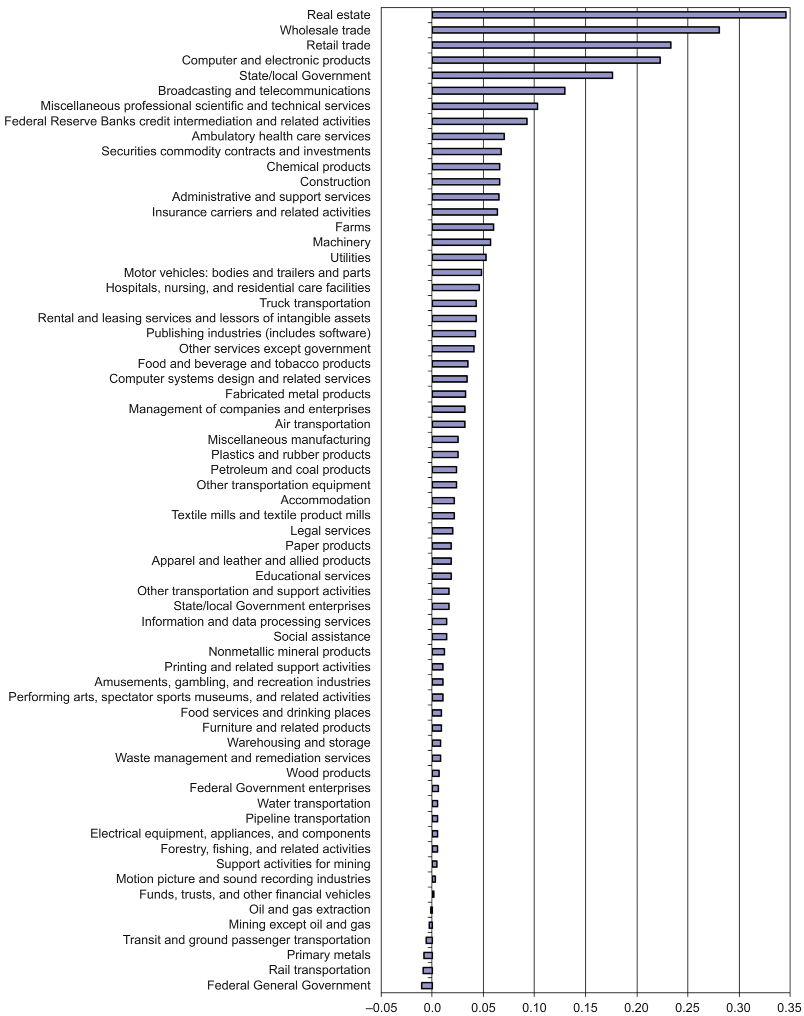
Figure 1.2
Contributions of Industry Groups to Value Added Growth, 1995–2012



The rate of growth of aggregate productivity also depends on the reallocations of capital and labor inputs among industries. The rate of aggregate productivity growth exceeds the weighted sum of industry productivity growth rates when these reallocations are positive. This situation occurs when capital and labor inputs are paid different prices in different industries and industries with higher prices have more rapid input growth rates. Weighted averages of industry capital and labor input growth rates then grow more rapidly than aggregate capital and labor inputs, such that the reallocations are positive. When industries with lower prices for inputs grow more rapidly, the reallocations are negative.

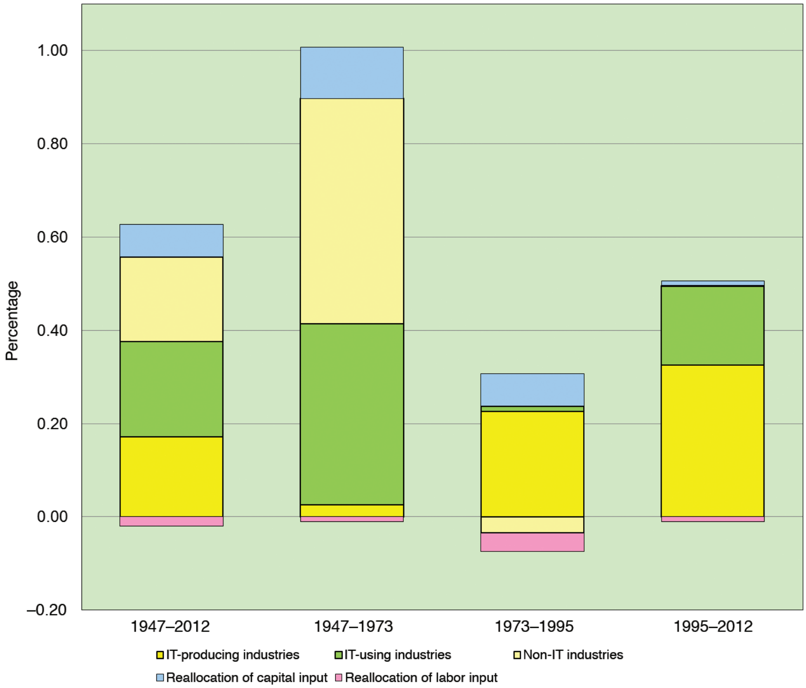
Figure 1.4 shows that the contributions of IT-producing, IT-using, and non-IT industries to aggregate productivity growth are similar in magnitude for the period 1947–2012. Non-IT industries greatly predominated in the growth of productivity during the Postwar Recovery, 1947–73, but this contribution became negative after 1973. The contribution of IT-producing industries was relatively small during this Postwar Recovery but became the predominant source of productivity growth during the Long Slump, 1973–95, and increased considerably during the period of Growth and Recession, 1995–2012.

Figure 1.3
Contributions of Individual Industries to Value Added 1947–2012



The IT-using industries contributed substantially to the U.S. productivity growth during the postwar recovery, but this contribution disappeared during the Long Slump, 1973–95, before reviving after 1995. The reallocation of capital input made a small but positive contribution to the productivity growth of the U.S. economy for the

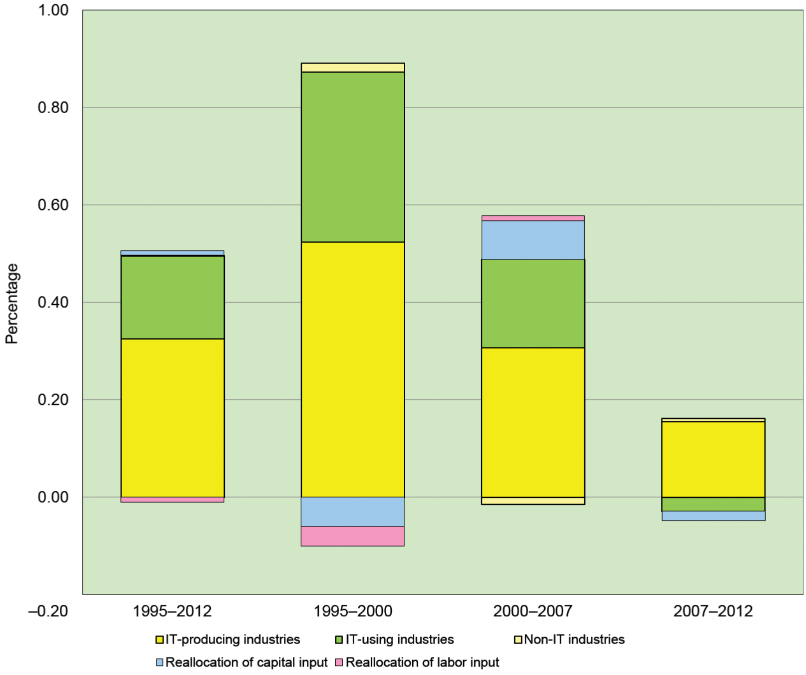
Figure 1.4
CONTRIBUTION OF INDUSTRY GROUPS TO
PRODUCTIVITY GROWTH, 1947–2012



period 1947–2012 and for each of the subperiods. The contribution of the reallocation of labor input was negligible for the period as a whole. During the Long Slump and the period of Growth and Recession, the contribution of the reallocation of labor input was slightly negative.

Considering the period 1995–2012 in more detail in Figure 1.5, the IT-producing industries predominated as a source of productivity growth during the period as a whole. The contribution of these industries remained substantial during each of the subperiods—1995–2000, 2000–2007, and 2007–12—despite the strong contraction of economic activity during the Great Recession of 2007–9. The contribution of IT-using industries was slightly greater than that of the IT-producing industries during the period of Jobless Recovery but dropped to nearly zero during the Great Recession. The non-IT industries

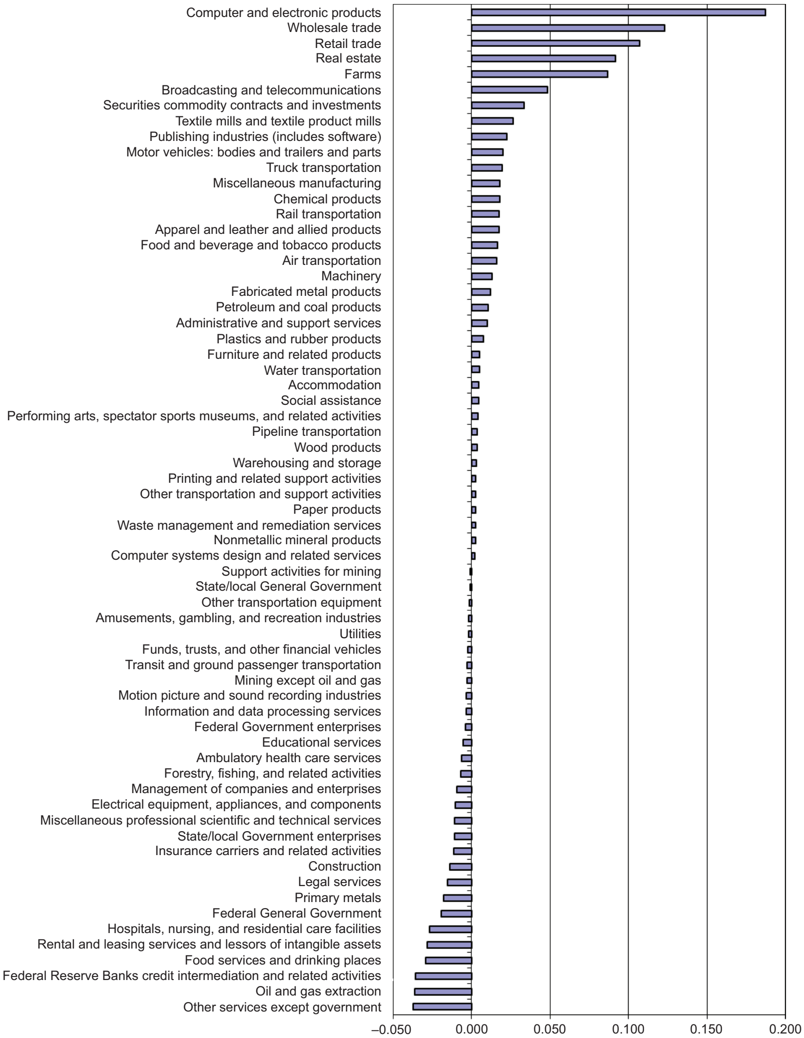
Figure 1.5
Contribution of Industry Groups to
Productivity Growth, 1995–2012



contributed positively to productivity growth during the Investment Boom of 1995–2000, but these contributions were negative during the Jobless Recovery and negligible during the Great Recession. The contributions of reallocations of capital and labor inputs were not markedly different from historical averages.

Figure 1.6 gives the contributions of each of the 65 industries to productivity growth for the period as a whole. Wholesale and retail trade, farms, computer and peripheral equipment, and semiconductors and other electronic components were among the leading contributors to U.S. productivity growth during the postwar period. About half the 65 industries made negative contributions to aggregate productivity for the period 1947–2012 as a whole. These include nonmarket services, such as health, education, and general government, as well as

Figure 1.6
CONTRIBUTIONS OF INDIVIDUAL INDUSTRIES TO PRODUCTIVITY GROWTH, 1995–2012



resource industries affected by resource depletion, such as oil and gas extraction and mining. Other negative contributions reflect the growth of barriers to resource mobility in product and factor markets due, in some cases, to more stringent government regulations.

The price of an asset is transformed into the price of the corresponding capital input by the cost of capital, a concept introduced by Jorgenson (1963). The cost of capital includes the nominal rate of return, the rate of depreciation, and the rate of capital loss due to declining prices. The distinctive characteristics of IT prices—high rates of price decline and price depreciation—imply that the cost of capital for the price of IT capital input is very large relative to the cost of capital for the price of non-IT capital input.

The contributions of college-educated and non-college-educated workers to U.S. economic growth are given by the relative shares of these workers in the value of output, multiplied by the growth rates of their labor input. Personnel with a college degree or higher level of education correspond closely with "knowledge workers" who deal with information. Of course, not every knowledge worker is college educated, and not every college graduate is a knowledge worker.

Figure 1.7 gives the sources of economic growth for the entire 1947–2012 period. Capital input growth is the dominant source, accounting for 1.62 points of the 3.05 percent average annual real gross domestic product (GDP) growth.[5] IT capital contributed an increasing share of this total capital over the three periods, while college-educated labor contributed an increasing share of total labor input. Total factor productivity (TFP) contributed only 20 percent of aggregate growth after 1947.

Figure 1.8 reveals that all of the sources of economic growth contributed to the U.S. growth resurgence during the 1995–2000 boom, relative to the Long Slump of 1973–95. Jorgenson, Ho, and Stiroh (2005) have analyzed the sources of the U.S. growth resurgence in greater detail. After the dot-com crash in 2000, the overall growth rate of the U.S. economy dropped to well below the long-term average of 1947–2012. The contribution of investment also declined below

[5] The sum of the value of capital and labor input is GDP at factor cost. The contribution of capital to aggregate growth is the growth of capital input weighted by the share of capital value in GDP. Similarly, the contribution of college-educated labor is the growth of college hours weighted by the share of college labor value in GDP.

Figure 1.7

Sources of U.S. Economic Growth, 1947–2012

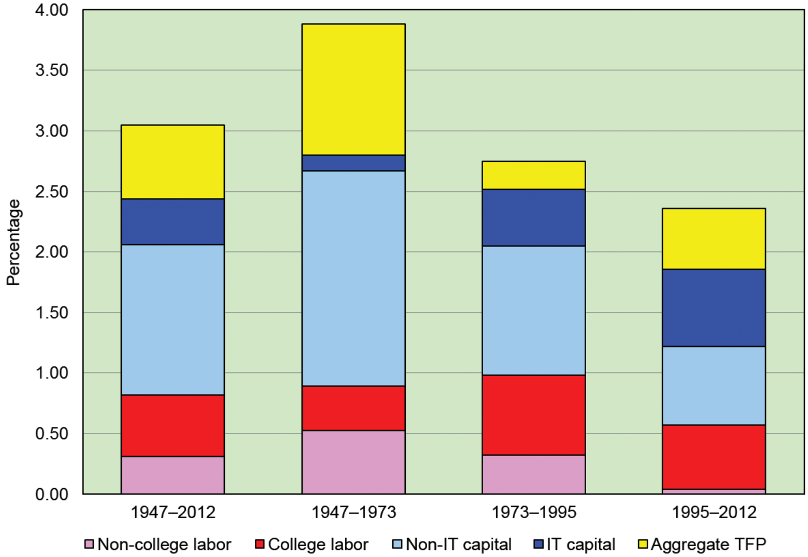
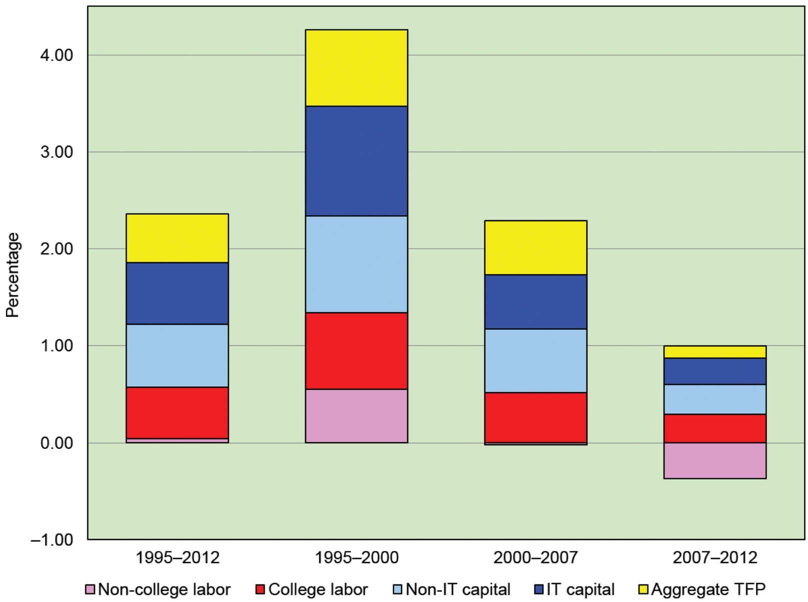


Figure 1.8

Sources of U.S. Economic Growth, 1995–2012



the long-term average, but the shift from non-IT to IT capital input continued. Jorgenson, Ho, and Stiroh (2008) argued that the rapid pace of U.S. economic growth after 1995 was not sustainable.

The contribution of labor input dropped precipitously during the period of Growth and Recession, accounting for most of the decline in the rate of U.S. economic growth during the Jobless Recovery. The contribution of college-educated workers to growth continued at a reduced rate, but that of non-college-educated workers was negative. The most remarkable feature of the Jobless Recovery was the continued growth in productivity, indicating a continuing surge of innovation.

Both IT and non-IT investment continued to contribute substantially to U.S. economic growth during the Great Recession period after 2007. Productivity growth fell, reflecting a widening gap between actual and potential growth of output. The contribution of college-educated workers remained positive and substantial, while the contribution of non-college-educated workers became strongly negative. These trends represent increased rates of substitution of capital for labor and college-educated workers for non-college-educated workers.

Future U.S. Economic Growth

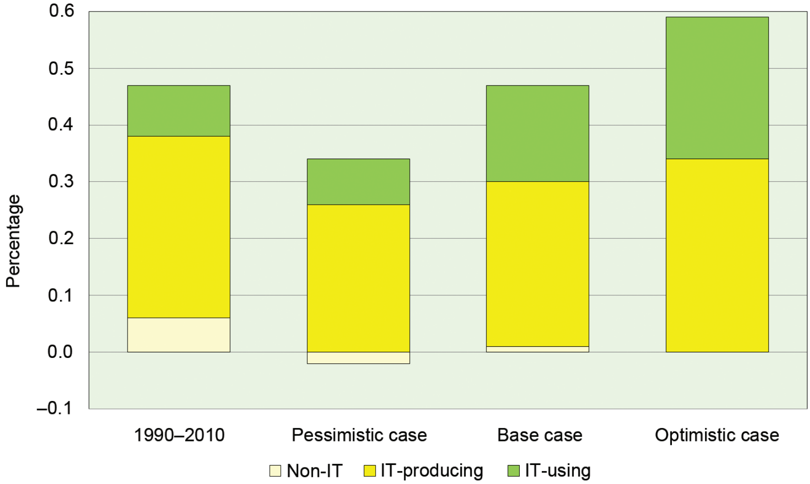
Byrne, Oliner, and Sichel (2013) have provided a recent survey of contributions to the debate over prospects for future U.S. economic growth. They give detailed evidence on the recent behavior of IT prices from research done at the Federal Reserve Board to provide deflators for the Index of Industrial Production. While the size of transistors has continued to shrink, the performance of semiconductor devices has improved less rapidly, severing a close link that had characterized Moore's law as a description of the development of semiconductor technology.[6] This view is supported by Unni Pillai (2011) and by the computer scientists John Hennessy and David Patterson (2012).[7]

Our projections for the period 2012–22 are summarized in Figures 1.9, 1.10, and 1.11. The methodology is adapted from Jorgenson, Ho, and Stiroh (2008) to incorporate projections of total factor productivity

[6] Moore's law is discussed by Jorgenson, Ho, and Stiroh (2005), Chapter 1.

[7] See John Hennessy and David Patterson (2012), Figure 1.16, p. 46. An excellent journalistic account of the turning point in the development of Intel microprocessors is presented in Markoff (2004).

Figure 1.9
Contribution of Industry Groups to Productivity Growth, 2012–2022



growth for IT-producing, IT-using, and non-IT industries. Like Jorgenson, Ho, and Stiroh, we present base-case, pessimistic, and optimistic projections of future growth in potential GDP. Our base-case projections are based on the average contributions of TFP growth for the three sectors for the period 1995–2012. Our optimistic projection omits

Figure 1.10
Range of Labor Productivity Projections, 2012–2022
Annual Percentage Growth Rates

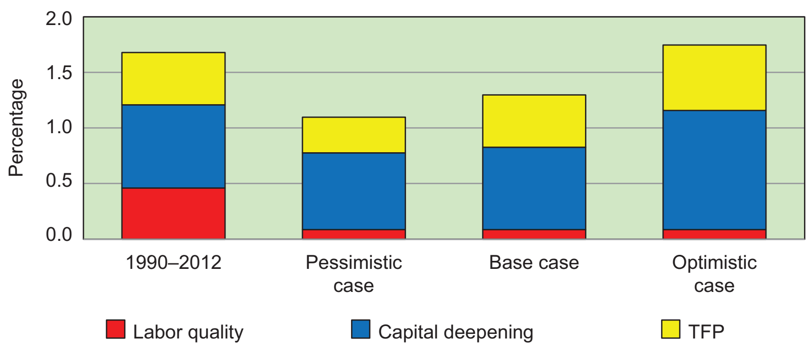
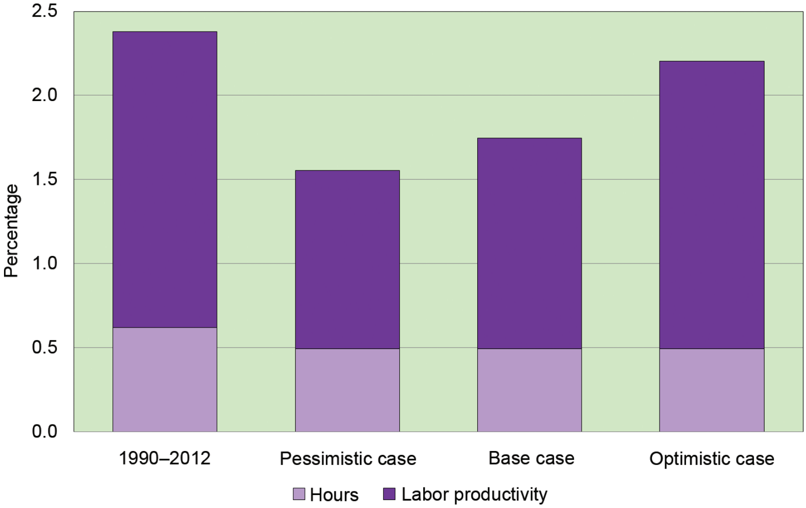


Figure 1.11
RANGE OF U.S POTENTIAL OUTPUT PROJECTIONS, 2012–2022
ANNUAL PERCENTAGE GROWTH RATES



the Great Recession period of 2007–12, while our pessimistic projection takes into account the final five years of the Great Recession and the Long Slump. We compare our projections with actual growth for 1990–2012.

Our base-case projection of growth in potential GDP in 2012–22 is 1.75 percent per year, compared with growth for 1990–2012 of 2.38 percent. The difference is due mainly to the projected slowdown in the growth of labor quality. Actual labor-quality growth is driven mainly by increases in average educational attainment. Rising educational attainment has been a major driver of U.S. economic growth throughout the postwar period. However, educational attainment will reach a plateau early in our projection period 2012–22. Labor-quality growth will fall from 0.459 percent per year during 1990–2012 to only 0.087 percent per year in 2012–22.

Our optimistic projection for potential U.S. GDP growth is 2.20 percent per year during 2012–22 as compared to actual growth of 2.38 percent per year in 1990–2012. The contributions of IT-using and non-IT industries along with more rapid growth in capital quality are mainly responsible for the increase in potential growth relative to actual growth. Our pessimistic projection for potential growth is only 1.56 percent per year. The difference from our base case is due mainly to a reduction in the projected growth of productivity in IT-producing and IT-using sectors and slower improvement in capital quality.[8]

Conclusion

Our industry-level data set reveals that replication of established technologies through the growth of capital and labor inputs, recently through the growth of college-educated workers and investments in both IT and non-IT capital, explains by far the largest proportion of U.S. economic growth. International productivity comparisons reveal similar patterns for the world economy, its major regions, and leading industrialized, developing, and emerging economies.[9] Studies are now underway to extend these comparisons to individual industries for the 40 countries included in the World KLEMS Initiative.[10]

Our new projections corroborate the perspective of Jorgenson, Ho, and Stiroh (2008), who showed that the peak growth rates of the U.S. Investment Boom of 1995–2000 were not sustainable. However, our projections are less optimistic, due mainly to the slowing growth of the U.S. labor force and the virtual disappearance of improvements in labor quality. Negative productivity growth during the Great Recession is transitory, but productivity growth is unlikely to return to the high rates of the Investment Boom and the Jobless Recovery.

Finally, we conclude that the new findings presented in this paper have important implications for U.S. economic policy. Maintaining the gradual recovery from the Great Recession will require a revival of investment in IT equipment and software and non-IT capital as well. Enhancing opportunities for employment is also essential, but this is likely to be most successful for college-educated workers. These measures will contribute to closing the substantial remaining gap between potential and actual output.

[8] These projections are not directly comparable with those summarized by Byrne, Oliner, and Sichel (2013), which are limited to nonfarm business.

[9] See Jorgenson and Vu (2013).

[10] See Jorgenson (2012).

Appendix: Projections

We adapt the methodology of Jorgenson, Ho, and Stiroh (2008) to utilize data for the 65 industries included in the U.S. National Income and Product Accounts. The growth in aggregate value added (Y) is an index of the growth of capital (K) and labor (L) services and aggregate growth in productivity (A):

$$\text{(A1)} \quad \Delta\ln Y = \bar{\nu}_K \Delta\ln K + \bar{\nu}_L \Delta\ln L + \Delta\ln A$$

To distinguish between the growth of primary factors and changes in composition, we decompose aggregate capital input into the capital stock (Z) and capital quality (KQ), and labor input into hours (H) and labor quality (LQ). We also decompose aggregate productivity growth into the contributions from the IT-producing industries, the IT-using industries, and the non-IT industries. The growth of aggregate output becomes

$$\text{(A2)} \quad \begin{aligned} \Delta\ln Y = {} & \bar{\nu}_K \Delta\ln Z + \bar{\nu}_K \Delta\ln KQ + \bar{\nu}_L \Delta\ln H + \bar{\nu}_L \Delta\ln LQ \\ & + \bar{\mu}_{ITP} \Delta\ln A_{ITP} + \bar{\mu}_{ITU} \Delta\ln A_{ITU} + \bar{\mu}_{NIT} \Delta\ln A_{NIT}\,, \end{aligned}$$

where the $\Delta\ln A_i$ s are productivity growth rates in the IT-producing, IT-using and non-IT groups and the $\bar{\mu}$'s are the appropriate weights. Labor productivity, defined as value added per hour worked, is expressed as

$$\text{(A3)} \quad \Delta\ln y = \Delta\ln Y - \Delta\ln H.$$

We recognize that a significant component of capital income goes to land rent. In our projections, we assume that land input is fixed, and thus the growth of aggregate capital stock is

$$\text{(A4)} \quad \Delta\ln Z = \bar{\mu}_R \Delta\ln Z_R + (1 - \bar{\mu}_R)\Delta\ln LAND = \bar{\mu}_R \Delta\ln Z_R\,,$$

where Z_R is the reproducible capital stock and $\bar{\mu}_R$ is the value share of reproducible capital in total capital stock.

We project growth using equation (A2), assuming that the growth of reproducible capital is equal to the growth of output, $\Delta\ln Y^P = \Delta\ln Z_R^{\,P}$, where the P superscript denotes projected variables. With this assumption, the projected growth rate of average labor productivity is given by

$$\text{(A5)} \quad \begin{aligned} \Delta\ln y^P = {} & \frac{1}{1-\bar{\nu}_K\bar{\mu}_R} \times [\bar{\nu}_K \Delta\ln KQ - \bar{\nu}_K(1-\bar{\mu}_R)\Delta\ln H + \bar{\nu}_L \Delta\ln LQ \\ & + \bar{\mu}_{ITP}\Delta\ln A_{ITP} + \bar{\mu}_{ITU}\Delta\ln A_{ITU} + \bar{\mu}_{NIT}\Delta\ln A_{NIT}]. \end{aligned}$$

We emphasize that this is a long-run relationship that removes the transitional dynamics related to capital accumulation.

To employ equation (A5), we first project the growth in hours worked and labor quality. We obtain population projections by age, race, and sex from the U.S. Census Bureau[11] and organize the data to match the classifications in our labor database (eight age groups, two sexes). We read the 2010 Census of Population to construct the educational-attainment distribution by age, based on the 1 percent sample of individuals. We then use the microdata in the Annual Social and Economic Supplement of the *Current Population Survey* to extrapolate the educational distribution for all years after 2010 and to interpolate between the 2000 and 2010 Censuses. This methodology establishes the actual trends in educational attainment for the sample period. Educational attainment derived from the 2010 Census shows little improvement for males compared to the 2000 Census, with some age groups showing a smaller fraction with professional degrees. There was a higher fraction with BA degrees for females.

We assume that the educational attainment for men aged 39 or younger will be the same as in the last year of the sample period; that is, a man who becomes 22 years old in 2022 will have the same chance of having a BA degree as a 22-year-old man in 2012. For women, this cut-off age is set at 33. For men over 39 years old, and women over 33, we assume that they carry their education attainment with them as they age. For example, the educational distribution of 50-year-olds in 2022 is the same as that of 40-year-olds in 2012, assuming that death rates are independent of educational attainment. Since a 50-year-old in 2022 has a slightly higher attainment than a 51-year-old in 2020, these assumptions result in a smooth improvement in

[11] The projections made by the U.S. Census Bureau in 2012 are given on its website: http://www.census.gov/population/projections/data/national/2012.html. In that projection, the resident population is projected to be 420 million in 2060. We make an adjustment to give the total population, including military personnel overseas.

educational attainment that is consistent with the observed profile in the 2010 Census.

The next step after constructing the population matrix by sex, age, and education for each year in the projection period is to calculate the hours-worked matrices along these dimensions. We do this by using the weekly-hours, weeks-per-year, and compensation matrices in 2010 described in Jorgenson, Ho, and Samuels (2014). We assume there are no further changes in the annual hours worked and relative wages for each age-sex-education cell and thus calculate the effective labor input in the projection period by multiplying these 2010 hours per year by the projected population in each cell and then weighting by the 2010 compensation matrix. The ratio of labor input to hours worked is the labor-quality index.

The growth rate of capital input is a weighted average of the stocks of various assets weighted by their shares of capital income. The ratio of total capital input to the total stock is the capital-quality index, which rises as the composition of the stock moves toward short-lived assets with high rental costs. The growth of capital quality during the period 1995–2000 was clearly unsustainable. For our base-case projection, we assume that capital quality grows at the average rate observed for 1995–2012. For the optimistic case, we use the rate for 1995–2007. Finally, we use the rate for 1990–2012 for the pessimistic case.

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2. The Rise and Fall of Exceptional U.S. Productivity Growth[1]

John Fernald, Mark Juneau, and Bing Wang[2]

The past decade has been a wrenching one for the U.S. and global economies. In the depths of the Great Recession, the unemployment rate in the U.S. economy rose to 10 percent, reflecting an economy operating far short of its potential. But as the effects of the Great Recession recede, and the unemployment rate returns to more normal levels, a key issue is how fast the economy can sustainably grow—its potential growth rate.

Here we emphasize that U.S. productivity growth, a key contributor to this sustainable pace, slowed prior to the Great Recession. The timing thus suggests that it is important to look at factors other than financial frictions, regulatory constraints, or policy changes since 2008. Indeed, in industry data, the slowdown after the early 2000s (prior to the Great Recession) is mainly accounted for by industries that produce information technology (IT) or that use IT intensively. Arguably, many of the transformative gains from reorganizing to take advantage of faster communications and information management were "one-offs" that were implemented by the early 2000s. Since then, incremental innovation has been ongoing—and, in the aggregate, it has added up to labor-productivity gains in the 1.0 to 1.5 percent per year range.

A reasonable guess is that the future will look like the recent past. Still, that future is enormously uncertain. It is very hard to know from where the important ideas of the future will come and whether machine learning and robots will, eventually, turn out to be game changers.

There are some policy steps that can help create a more positive environment for innovation and future growth. One is to maintain

[1] This chapter draws heavily on Fernald (2014a) and Fernald and Wang (2015).

[2] John Fernald and Bing Wang are at the Federal Reserve Bank of San Francisco. Mark Juneau is at Alliant Employee Benefits, San Francisco. The views in this paper are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of San Francisco or anyone else associated with the Federal Reserve System or Alliant Employee Benefits.

demand in the short run—to move the economy closer to full employment—since a healthy macroeconomic environment is likely to be better at fostering innovation. But of course, stabilizing demand by households, businesses, and government is not a source of long-term innovation. Rather, such innovation requires a fluid, dynamic, and competitive environment for businesses. Policies that encourage the domestic generation of ideas may also be positive factors.

Such an environment can be demanding and risky for individuals. Policies that help prepare workers for a volatile and unpredictable environment can support the ability of affected workers to continue contributing to—and benefiting from—growth, with education at the top of the list.

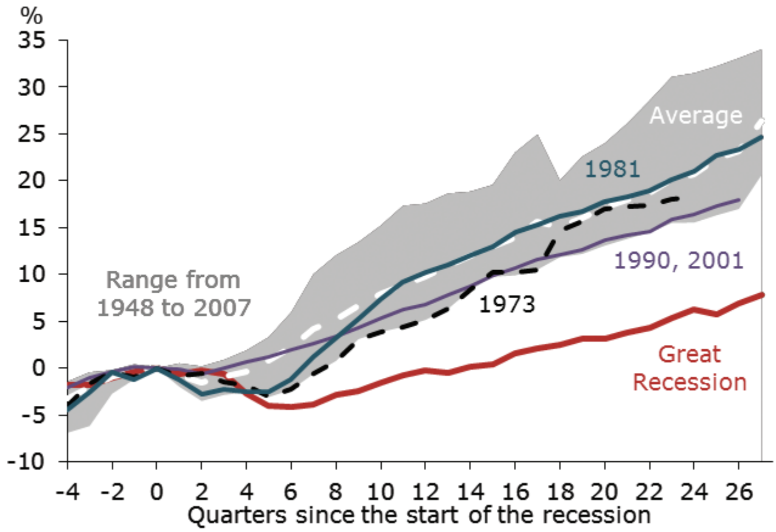
Backdrop: Slow Underlying Growth *and* Slow Closing of Gaps

The recovery that followed the Great Recession has been the most disappointing since World War II. This slow recovery could reflect problems on the supply side of the economy—such as weak underlying productivity growth. It could also reflect a shortage of aggregate demand, as cautious households, businesses, and cash-constrained governments have not spent enough to keep production in line with the economy's productive potential. Both factors have played a role. Underlying productivity trends have, indeed, been weak—as the rest of this chapter highlights. But it is important to keep in mind that the economy's weakness has not solely reflected supply-side problems.

To help us see the issues, Figure 2.1 compares the path of gross domestic product (GDP) during and after the Great Recession to the experience in previous postwar recessions. In each case, quarter zero marks the beginning of a recession, using National Bureau of Economic Research business-cycle dates. Thus, for the Great Recession, quarter zero is 2007:Q4. Selected previous recessions are shown explicitly, with the shaded region encompassing the range of experience following all recessions prior to the Great Recession (using data going back to 1948).

The Great Recession was the deepest postwar recession. Indeed, GDP fell 4.2 percent below its 2007:Q4 peak. But despite the depth, the recovery was strikingly shallow. Previous deep recessions, such as the ones that started in 1973 and in 1981, were marked by rapid recoveries. Following the Great Recession, not only did output never catch up to the previous postwar range, but it has continued diverging from previous experience.

Figure 2.1
CUMULATIVE CHANGE IN GDP SINCE BUSINESS-CYCLE PEAKS

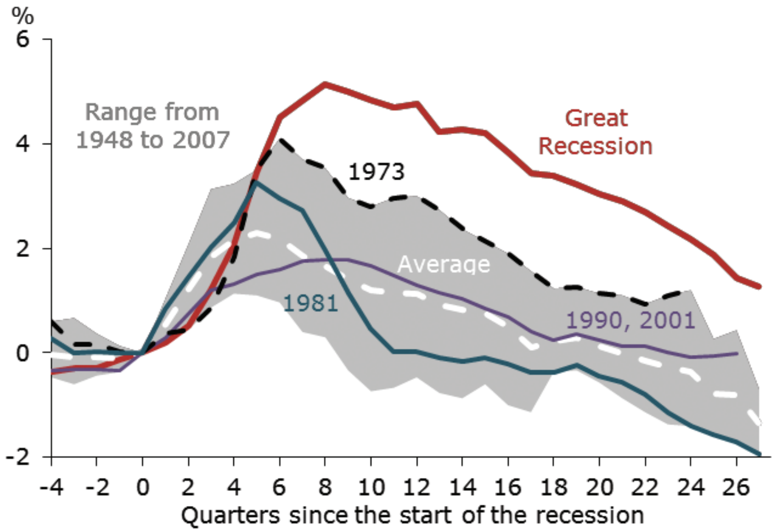


SOURCE: Bureau of Economic Analysis (BEA).
NOTES: Indexed to zero at business-cycle peaks as denoted by the National Bureau of Economic Research. When necessary, postrecession experience is truncated at the end of the ensuing expansion, that is, the beginning of the next recession. Only selected recessions are shown, but the shaded region encompasses the full range of experience following recessions prior to the Great Recession. For the Great Recession, quarter zero is 2007:Q4 and quarter 27 is 2014:Q3.

Although we later highlight supply-side weakness that largely predated the Great Recession, the recovery has also been marked by a remarkably slow recovery in aggregate demand. Figure 2.2 sheds light on this issue by comparing the unemployment experience with previous recessions and recoveries. The unemployment rate has stayed elevated for an exceptionally long time. Little of the increase in unemployment appears to have reflected disruptions in labor markets.[3] Rather, most appears to be a consequence of a sustained shortfall in aggregate demand, which led resource gaps to close slowly. The reasons

[3] See Elsby, Hobijn, and Sahin (2013).

Figure 2.2
CHANGE IN UNEMPLOYMENT SINCE BUSINESS-CYCLE PEAKS



SOURCE: Bureau of Labor Statistics (BLS).
See notes to Figure 2.1.

why spending has been constrained are plentiful and intuitive.[4] These include scared consumers who spent cautiously in order to pay down household debt; businesses that have been hesitant to invest because of uncertainty about the strength of the recovery or because of political infighting in Washington;[5] cash-constrained local governments that cut spending and fired workers; declining inflation-adjusted federal spending since 2010;[6] and a weak global economy.

[4] See, for example, Williams (2013), who wrote, "The main point I want to convey is that, although the events of the past six years have undeniably left their mark on the supply side of the economy, the primary reason unemployment remains high is a lack of demand."

[5] See Leduc and Liu (2014).

[6] As of 2014:Q3, real federal spending per capita was about 4.5 percent below its mid-2010 peak. The only comparable decline in real federal spending since World War II was the draw down after the Korean War. Data are nominal government expenditures from U.S. National Income and Product Accounts Table 3.1 (direct government purchases plus transfers), deflated by the PCE chained price index (Table 1.1.4), then divided by Census estimates of resident population.

Nevertheless, by late 2014 (i.e., by 27 quarters after the start of the recession), the unemployment rate had retraced much of its increase. This suggests that much, though far from all, of the slack in labor markets had diminished. Thus, if the economy had no labor-market slack at all, the level of output would plausibly be only modestly higher than it actually is. For example, the usual Okun's law rule of thumb suggests that, were the unemployment rate a percentage point lower, output would be 2 percent higher.[7] That would still leave GDP well below the previous range of experience shown in Figure 2.1. That, in turn, implies that much of the weak growth shown in that figure was in fact structural, reflecting slow growth in potential output.

We now turn to a key aspect of potential growth, which is underlying trends in productivity.

The Pre–Great Recession Slowdown in Productivity Growth

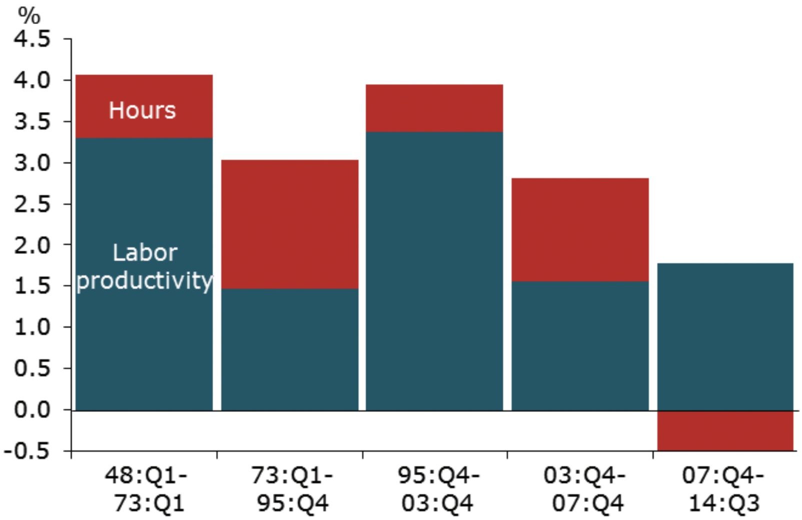
Output growth can be decomposed into hours worked and labor productivity, or output per hour. Figure 2.3 shows this decomposition for the U.S. business sector, where it is possible to do careful accounting of the factors explaining growth. The contributions of both hours and productivity have varied over time. From the early 1970s through 1995, productivity in the business sector rose about 1.5 percent per year. Between 1995 and 2003, that pace more than doubled to a rate comparable to its fast pre-1973 pace. Considerable evidence suggests this late 1990s acceleration reflected the production and use of IT. We return to the IT story below.

Over the past decade, the exceptional 1995–2003 pace of productivity growth has disappeared, leaving growth at roughly its pre-1995 pace. In particular, note that productivity growth was similar in the four years leading up to the Great Recession to what it has been since. Indeed, Fernald (2014a) argues that by 2014 the level of productivity was little affected by the Great Recession and its aftermath. Thus, the slowdown in trend productivity predates the Great Recession.

Of course, Figure 2.3 shows that hours worked have also declined since the Great Recession—despite the fact that the population of roughly working age (from 16 through 64) has increased at

[7] See, for example, Daly et al. (2015).

Figure 2.3
CONTRIBUTIONS TO BUSINESS-SECTOR OUTPUT GROWTH,
AVERAGE ANNUALIZED GROWTH RATE



SOURCES: BEA, BLS, and the authors' calculations.

0.7 percent per year over this period. But, as already noted, weak aggregate demand associated with the deep recession and slow recovery, as well as some labor-market disruptions, has harmed employment. Thus, the sluggish output growth since 2007 reflects poor productivity trends that *predate* the recession, along with labor-market shortcomings since.

What determines trend labor-productivity growth? One factor is worker skills, such as education and experience. A second factor is growth in the equipment, structures, and intellectual capital that workers have to work with. When firms invest in new plants or automate a process, each worker has more or better "tools," or capital, to work with and should be able to produce more during each hour worked.

Fernald (2014a) finds that these two factors cannot explain the slowdown in productivity after 2003. For example, the average educational attainment of the workforce has continued to increase, which raises productivity. And although capital growth has been subdued since the Great Recession—reflecting the weak economy—hours worked have fallen since 2007. So capital per hour worked has continued to grow modestly.

Rather, the important factor after 2003 is slower growth in innovation. The economy-wide effects of innovation are typically measured indirectly as the residual part of productivity growth that cannot be explained by other factors. This measure is known as total factor productivity (TFP). In the long run, TFP captures a broad notion of "innovation"—including the productivity benefits from formal and informal research and development, improvements in management practices, reallocation as high-productivity firms drive out low-productivity firms, and the productive benefits of government-provided infrastructure.

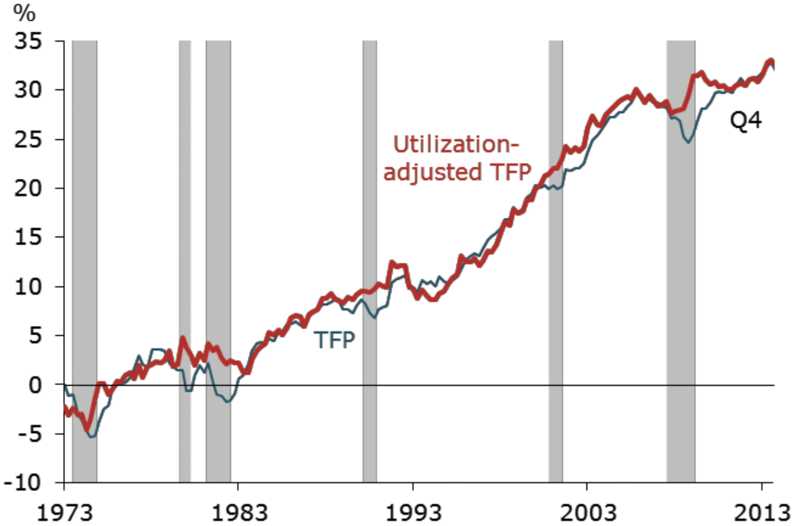
Figure 2.4 shows two measures of the level of TFP. The blue line is the standard measure. It shows that growth sped up in the mid-1990s and slowed down since the mid-2000s. Indeed, the level of TFP was declining in the years prior to the Great Recession.

During the Great Recession itself, TFP initially fell further. This does not mean that innovation reversed course. In the short run, TFP fluctuates with demand as firms vary how intensively they use their capital and labor. For example, when the economy goes into recession and demand falls, firms may want to retain much of their existing workforce if they believe the reduced demand is temporary. In that case, with a similarly sized workforce producing less output than before, measured labor productivity and TFP falls. Conversely, when demand recovers, firms have excess capacity and can quickly ramp up production without needing substantial investment or hiring; so productivity surges. TFP shows this pattern in 2009 and 2010.

Fernald (2014b) provides an alternative measure of TFP, shown by the red line that adjusts for these variations in utilization.[8] Prior to the Great Recession, utilization-adjusted TFP behaved similarly to standard TFP—with fast growth from the mid-1990s to the early to mid-2000s and slow growth thereafter. During the recession, as expected, their behavior is very different. Nevertheless, this measure

[8] See Fernald (2014b) and Basu, Fernald, and Kimball (2006) for details.

Figure 2.4
TFP and Utilization-Adjusted TFP,
Cumulative Growth Rate Since 1973:Q2



Source: Fernald (2014b).

shows the same broad pattern of fast growth in the late 1990s and early 2000s and slower growth since. By 2012 or 2013, the effects of variations in resource utilization were no longer important quantitatively.[9]

Despite the short-term disruptions associated with the Great Recession, Figures 2.3 and 2.4 make clear that the slowdown in labor productivity and TFP predated the Great Recession. This result is surprising since there is no shortage of reasons why a financial crisis might cast a "long shadow" on productivity growth. For example, a financial crisis such as the Great Recession might affect the level

[9] The temporary spike in utilization-adjusted TFP during the recession could have reflected panicked firms that pushed for temporary, unsustainable efficiency gains, or unusual effort by fearful workers as documented by Lazear, Shaw, and Stanton (2013). Lazear, Shaw, and Stanton track task-level productivity at a single firm. Productivity rose as the Great Recession began. When the recession ended, task-level productivity declined—much like utilization-adjusted TFP.

or growth rate of economy-wide innovation because of credit constraints on innovative firms,[10] the degree of productivity-improving reallocation,[11] or other channels. Prescott and Ohanian (2014) focus on the possible adverse effects of regulations that have gone into effect since 2008.

But the fact that the slowdown predated the Great Recession suggests that these factors are probably modest relative to the substantial pre–Great Recession slowdown in TFP growth.

An Easing in the IT Revolution?

Fernald (2014a) looks to industry data for clues about why aggregate TFP growth slowed. He finds that the pre–Great Recession slowdown was in sectors that *produce* IT or that *use* IT intensively.

The hypothesis that IT was the culprit is natural. As noted above, a large literature links the mid-1990s speedup in TFP growth to the exceptional contribution of computers, communications equipment, software, and the Internet. Indeed, IT has had a broad-based and pervasive effect on the economy through its role as a "general-purpose technology"—that is, one that fosters complementary innovations such as business reorganization to take advantage of an improved ability to manage information and communications. But by the early 2000s, industries such as retailing may have already been substantially reorganized, after which the gains from further innovation might have been more incremental than transformative.

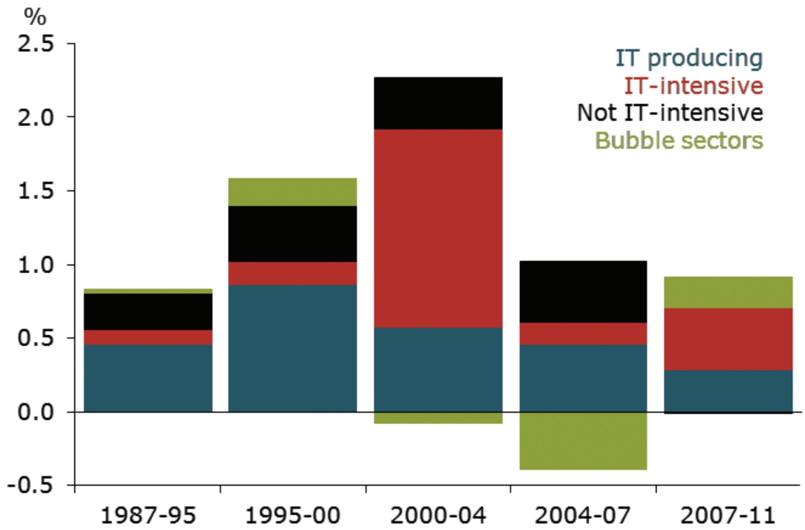
Figure 2.5 shows evidence from industry TFP data in favor of the IT hypothesis. The bar chart decomposes business-sector TFP growth (as plotted in Figure 2.4) into industry sources. (The data for this detailed decomposition run only from 1987 to 2011, so they start later and end earlier than the data in Figure 2.4.) The height of the bars shows TFP growth for the time periods shown. Although cyclical factors from the Great Recession do not appear important after 2013 or so, these factors may still have mattered in 2011. So we focus our discussion on the prerecession period. That said, the main conclusions are robust with respect to the entire 2004–11 period.

One slice of the data focuses on the "bubble" sectors of the mid-2000s—that is, construction, real estate, finance, and natural-resource

[10] See Liu and Wang (2014).

[11] See Petrosky-Nadeau (2013).

Figure 2.5
CONTRIBUTION TO TFP GROWTH BY INDUSTRY SUBGROUP
(ANNUAL PERCENTAGE CHANGES)



SOURCES: BEA, BLS, and Fernald (2014a).
NOTES: Aggregate TFP growth based on BLS industry data is decomposed into four mutually exclusive categories as shown. "Bubble sectors" are construction, finance, real estate, agriculture, and mining. IT-intensive and not-IT-intensive are based on BLS estimates of payments for IT as a share of value added. They are defined so that they account for the same share of GDP. See Fernald (2014a) for further details.

industries. These industries behaved in unusual ways in the mid-2000s—with the housing boom and subsequent bust, excesses in the financial sector, and surging commodity prices. The contribution of these industries to overall TFP fell—becoming more negative—from 2000 to 2004 and 2004 to 2007. But the contribution of the remaining three-quarters of the economy fell even more, as shown by the bars that lie above zero.

These nonbubble sectors are divided into three mutually exclusive pieces: IT-producing, IT-intensive, and non-IT-intensive. The latter two categories are based on Bureau of Labor Statistics data on estimated payments for IT capital as a share of industry value added.

These two categories are divided so that their total sizes, measured in terms of GDP, are the same.

As Figure 2.5 shows, the TFP slowdown is concentrated in industries that produce IT or that use IT intensively. The contribution of IT producers was inordinately high in the late 1990s, accounting for over half of overall TFP growth in this period, even though they account for only 5 percent of the economy. Much of that surge reflected gains in hardware production, in part because competition within the semiconductor industry led to the faster introduction of new chips. In the 2000s, the pace of TFP gains in IT production eased. Hence, the direct contribution of IT-producing industries fell.

In the early 2000s, the contribution of intensive IT-using industries bulged, but then it receded markedly in the 2004–7 period. This group of industries includes, among others, broadcasting and telecommunications, wholesale trade, utilities, some services (such as professional, scientific, and technical), and a few manufacturing industries (such as chemicals). That pattern is consistent with the view that benefiting from IT takes substantial intangible organizational investments that, with a lag, raise measured productivity. By the mid-2000s, the "low-hanging fruit" of IT-based innovation had been plucked.[12]

What Does the Future Hold?

Three out of the past four decades have seen business-sector productivity growth in the 1–1.5 percent range, suggesting that this could be a rate consistent with the ongoing innovation over this period.

Going forward, that may be too pessimistic a forecast by entirely discounting the fast growth from 1995 to 2003. After all, what we've seen may be simply a pause in the ongoing IT revolution. Fernald (2014a) uses a statistical method that weights recent observations more than past observations and suggests a slightly faster pace of just under 1.9 percent per year. With reasonable assumptions about the nonbusiness sector and demographics, that would translate into GDP growth of 2.1 percent per year and growth in GDP per hour worked of 1.6 percent. This pace of per-hour gains is similar to the average pace from 1973 through 2007.

[12] See also Gordon (2014) and Cowen (2011).

But uncertainty about future productivity growth is high. Statistically, based on post–World War II quarterly data, Müller and Watson (2014) estimate that there is a 90 percent chance that growth of nonfarm-business labor productivity over the next 25 years will average between 0.7 and 3.3 percent per year. The highs and lows of that range have dramatically different implications for growth in living standards and government budgets.

Fernald and Jones (2014) discuss some of the economic sources of that uncertainty for a country at the frontier of knowledge such as the United States. In their model, growth in productivity ultimately comes from growth in ideas. And the development of new ideas, in turn, depends on the number of researchers who are seeking new ideas as well as on the stock of previously discovered ideas.

In the longer run, since ideas (eventually) flow across borders, what matters is the creation of ideas globally. Over the past century, it was primarily the case that research at the frontier was done in a small number of countries, especially the United States, a few European countries, and Japan. Jones (2002) and Fernald and Jones (2014) find that growth in GDP per hour worked has been constant or slowing, despite an increasing share of workers and resources dedicated to research. That suggests that the U.S. and global economies have had to work harder and harder to maintain productivity growth. In other words, new ideas have gotten harder to find, but that has been offset by increasing research intensity. But since the number of researchers cannot permanently grow relative to the population, it implies that the per-person growth rate we've seen historically may not be sustainable.

Nevertheless, even in the context of that model, the return to sustainable, steady-state growth need not be imminent. In the next few decades, the global economy may well be able to keep devoting more resources to research. An important reason is that countries such as China, South Korea, and India are now doing research that is relevant for advanced economies such as the United States. Effectively, the pool of people looking for new ideas (and new applications of existing ideas) has gotten larger.

Even more speculatively, a key issue is how ongoing research effort translates into useable ideas. Pessimists argue that IT is less important than great innovations of the past that dramatically boosted productivity, such as electricity or the internal combustion engine.[13] Optimists point to the possibilities offered by robots and machine learning.[14] The promise of machine learning suggests that the "technology" for discovering new ideas may be different in the future than in the past. Economic history suggests that it is hard to know until well after the fact how revolutionary any particular innovation will turn out to be.

What Is to Be Done?

We briefly consider policy steps that can help foster innovation and make it work for society broadly.

First, we have argued that productivity slowed prior to the Great Recession—not, primarily, because of it. Still, prolonged economic weakness is likely to do further harm to future productivity growth.

For example, Comin and Gertler (2006) argue that business-cycle downturns may propagate through reduced innovation and implementation of ideas. Sedláček and Sterk (2013) find that not only did the number of U.S. startups drop sharply during the Great Recession, but recession-born firms tend to be less productive than others even when the economy recovers. Concern that a long period of inadequate demand may harm innovation could be even more salient for Europe, where there has been little progress at all in closing output or unemployment gaps, than for the United States.[15]

Together, these arguments point to a straightforward policy recommendation to keep the economy close to full employment if possible. Reifschneider and coauthors (2013) quantify the implications of supply-side concerns for monetary policy. In their model, a desire to mitigate supply-side damage leads to a more accommodative monetary policy than would otherwise be the case. The International Monetary Fund (2014) argues for infrastructure investments as a way to boost both demand in the near term and supply in the longer term.

[13] See Gordon (2014).

[14] See Brynjolfsson and MacAfee (2014).

[15] The Organization for Economic Cooperation and Development (OECD) estimates that for the euro area, the output gap in 2014 is larger than it was in 2009. For the United States, the gap has steadily narrowed since 2009, consistent with the unemployment evidence in Figure 2.2 (OECD output gap estimates obtained from Haver Analytics).

Second, whatever happens on the demand side, the major productivity gains—from IT or elsewhere—will rely on private-sector activities to develop and implement new products and new business ideas. That suggests a need for economic fluidity and dynamism to take advantage of growth opportunities.

One indirect piece of evidence that dynamism and flexibility matter for productivity comes from a comparison of the United States and Europe regarding the gains from IT. Europe invested in computers but didn't get the same productivity benefits after 1995. Much of the research points to labor- and product-market inflexibilities that limit the ability to reorganize to benefit from IT.[16] For the United States, Davis and Haltiwanger (2014) suggest that the dynamism of the U.S. economy, by many measures, has been declining for decades for reasons that are not yet fully understood. Enhancing the ability of firms to adapt to innovation would plausibly provide a boost to growth.

Third, a potential cost of fluidity and dynamism is a heightened degree of individual uncertainty. Indeed, not all workers appear likely to benefit equally from innovation: there will be winners and losers. One area for policy to focus on is education and skill development to allow more people to take advantage of the opportunities that innovation brings.[17] Maintaining an appropriate social safety net can help individuals to weather the volatility and upheaval that may accompany ongoing change. This support at the individual level would help ensure that those workers who are negatively affected are able to adapt and make a positive contribution rather than being "left behind" and failing to contribute to the economy.

Finally, there are a range of other policies that might help foster innovation and the spread of ideas, such as adequate funding for basic research. An open question is the role of immigration policy that encourages the domestic generation of ideas. In the model used by Fernald and Jones (2014) and discussed above, ideas flow freely across borders. But that model assumes that idea generators locate where they are most productive; in other words, in that model, barriers

[16] See Van Reenen et al. (2010). Bartelsman (2013) argues that, with suitable reforms, Europe has considerable scope to boost productivity through improved reallocation of resources associated with IT.

[17] Acemoglu and Autor (2012).

to movement by innovators would harm growth. In addition, even though the U.S. economy benefits from ideas generated elsewhere (e.g., from emerging research and development efforts in China or India), in a model where ideas diffuse slowly—or have positive local spillovers—it would likely be the case that the U.S. economy would benefit disproportionately when the innovation is "home grown."

Conclusions

The early-2000s slowdown in productivity growth predated the Great Recession of 2007–9. Hence, it does not appear related to financial or other disruptions associated with that event. Rather, it appears to mark a pause—if not the end—of exceptional productivity growth associated with IT. Many transformative IT-related innovations showed up in the productivity statistics in the second half of the 1990s and early 2000s. Over the past decade, however, the gains may have become more incremental. Still, there is enormous uncertainty about what the future holds for growth. At least at the margins, fostering innovation and supporting the ability of firms and workers to benefit from the generation of new ideas may positively affect future growth.

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3. Explanations for Slow Long-Term Growth

Martin Neil Baily and Barry P. Bosworth[1]

Introduction

The long, drawn-out recovery from the 2007–9 recession is now perceived as largely complete. In his 2015 State of the Union speech, President Barack Obama said, "The shadow of crisis has passed, and the State of the Union is strong." The unemployment rate, at 5.3 percent as of June 2015, is below the 5.5 percent level that the Congressional Budget Office (CBO) has long characterized as full employment. Employment creation has been strong, and capacity utilization of the industrial sector is also close to its precrisis average of 80 percent.

A closer look at the economy, however, shows some troubling signs. The improvements in these standard measures of resource utilization are largely the product of reduced supplies of labor and capital rather than of increased demand. A dramatically lower rate of labor-force participation is now accepted as the new normal and the capital stock is expanding at only half of the precrisis rate. These reductions in factor supplies, together with sluggish growth in total factor productivity (TFP), have led the CBO to lower its estimated level of potential output in 2014 by 7 percent since the onset of the recession, and it has cut projected average annual growth by about one-half of a percentage point, from 3 to 2.5 percent, relative to precrisis expectations. Thus, the economic losses from the recession seem increasingly permanent and not just a transitory business-cycle phenomenon.

The goal of this chapter is to examine alternative explanations for the apparent slowing of the long-run rate of U.S. economic growth.

[1] Martin Neil Baily and Barry P. Bosworth are senior fellows with the Brookings Institution. The authors are indebted to Mattan Alalouf and William Bekker for research assistance and to Harry Holzer for helpful suggestions.

The first possibility is that weakness on the demand side of the economy has had an impact on aggregate supply, particularly on labor-force participation and capital investment. The extended recession may have hurt longer-run growth. A second explanation is that the pace of innovation has slowed, reducing the pace of TFP growth and cutting the incentive for investment. A third possibility is that the nature of innovation has shifted, creating a mismatch between the skills of the workforce and the demand for labor (a skill bias). Biased technological change combined with increased globalization has pushed the bulk of the workforce into low-skill, low-wage activities that have dragged down average labor productivity.

Has the Recession Adversely Impacted Aggregate Supply?

The failure to recoup the losses from the recession represents a major break from the experience of past U.S. business cycles. In a paper that included an extensive review of prior studies, Kim and Murray (2002) concluded that three-fourths or more of a typical recession was transitory, with only weak evidence of any permanent impact on the long-run growth path. Most recently, Papell and Prodan (2012) argued that even severe recessions have only transitory effects on the path of long-run growth. Bernanke (2011) also reasoned that the long-run growth potential of the United States should not be materially affected by the crisis. However, other studies that focus specifically on financial crises have reached more pessimistic conclusions (Reinhart and Rogoff 2009).

The estimates of potential gross domestic product (GDP) constructed by the CBO provide a useful framework for thinking about how to evaluate the effects of the recession on aggregate supply. Its consequence for long-term growth can be measured through its effect on growth in the three primary determinants of potential output: the supply of labor, the stock of capital, and TFP. The CBO recently published a review of its revisions to potential output since the onset of the recession in 2007 (CBO 2014). The current estimate of potential GDP for 2017 is 7.4 percent below the estimate published in 2007. In its report, however, the CBO attributes only a small portion of the downward revision (1.8 percentage points) to the recession and weak recovery. The largest change is the result of a reassessment of prior trends in the factor inputs and productivity (4.8 percentage points), which the CBO does not associate directly with the recession. However, we will use the CBO framework to explore the impact of the financial recession on labor supply, capital accumulation, and productivity.

Labor Supply

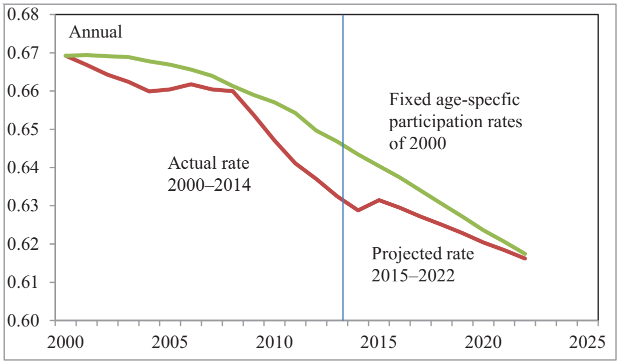
The aggregate labor-force participation rate has fallen substantially since the onset of the recession, from 66 percent in 2007 to 62.9 percent in 2014. The general view of labor economists has been that labor-force participation—particularly that of prime-age workers—is only weakly affected by business-cycle conditions. Hence, the magnitude of the drop in the labor-force participation rate since the latest recession has been a surprise. And there is considerable debate about the extent to which the loss is permanent.

A substantial portion of the decline can be attributed to the effects of demographic change as the large Baby Boom generation ages and sees lower rates of labor-force participation. This is illustrated in Figure 3.1 by holding labor-force participation rates within five-year age brackets constant at the values of 2000, the peak year for the overall participation rate, and tracing out the effects of changes in the age distribution of the noninstitutional population. As shown in the figure, about two-thirds of the 4.1 percentage point drop in the participation rate between 2000 and 2014 can be attributed to a simple shift in the composition of the working-age population toward older workers with lower rates of labor-force participation. That pattern is projected to continue into the future, with a further demographically induced fall in the participation rate of 2.6 percentage points by 2022.[2]

Changes in the overall participation rate are a function of four factors: demographic changes in the composition of the population, secular changes within specific groups, possible cyclical influences, and purely random effects. The demographic component can be foreseen with a high degree of accuracy and should not be a surprise. Most of the recent debate has been the result of unforeseen shifts in the group-specific participation rates and disagreements about the extent

[2] The precise meaning of the term "demographic effects" can cause confusion. In this case, it is limited to changes in the composition of the population, since the age-specific participation rates are held at their 2000 values. However, other analyses could reasonably allow for trend changes in the participation rates of subgroups while still excluding any behavioral response to economic determinants.

Figure 3.1
ACTUAL AND DEMOGRAPHICALLY
ADJUSTED LABOR-FORCE PARTICIPATION, 2000–2022



SOURCES: The actual labor-force data are from the Bureau of Labor Statistics (BLS), and the projections are from Toossi (2013). The demographic-adjusted rate is computed by the authors from BLS data on the labor force and population in five-year age groups using fixed participation rates of 2000.

to which they reflect the short-term, hopefully cyclical, deterioration of the labor market or more permanent changes. For example, participation rates of teenagers and young adults have been declining for many years, but the drop was particularly large after 2000. Within the prime-age group (25–54), the male participation rate has been slowly falling for some time, but the prior pattern of a rising participation rate of women began to slow in the 1990s and actually turned down in the 2000s. As a partial offset, the participation rates of older men and women have been rising, and that pattern accelerated after 2000.

The Bureau of Labor Statistics, the Congressional Budget Office, and the Social Security Administration all have maintained active programs of labor market research that produce periodic projections of future changes in labor-force participation rates. A 2006 study (Aaronson et al.), undertaken prior to the crisis, reported 10-year projections for the above three age groups together with the study's own estimates. The three age-group forecasts embodied quite similar patterns of gradual decline, with overall participation rates in 2013 in a narrow range of 65–66 percent that was in retrospect too high. The study by Aaronson and coauthors was closer to the actual outcomes because it predicted significantly larger declines for the young and prime-age workers. In subsequent years, the Bureau of Labor Statistics (BLS) and the CBO have brought down their projections, treating the lower-than-expected participation rates as a permanent phenomenon.[3] With each projection, they begin with the last known value and project the participation rate to fall further in future years but by less than implied by a simple demographically adjusted projection. Thus, both the CBO and the BLS have lowered their 10-year projections by the amount of the recent shortfall. In their latest projections, the CBO and BLS are in basic agreement through 2024 in anticipating further declines in the participation rate of about two percentage points over the next 10 years.

However, it is also important to note, as in Figure 3.1, that the demographically adjusted measure of the labor force will also continue to fall. Effectively, the BLS and CBO projections assume that the gap between the demographic and actual participation rates is a transitory or cyclical phenomenon that will gradually fade away, such that the projected rate matches the simple demographic extrapolation of fixed participation rates by 2022. The assumption that the gap will diminish seems to have been borne out in the aftermath of the 2001 recession, in which the difference between the two measures had largely disappeared by 2007. The magnitude of the gap is larger now, however, and it appears to be growing rather than shrinking.

In addition to lowering its predictions of the future labor force, the CBO has reduced estimated hours per worker in 2017 compared to the projections that it prepared in 2007. However, the change is small, amounting to about 1.5 percent. Surprisingly, the recession has not had a great effect on hours per employee despite the frequent references to the increase in the number of workers who are involuntarily working part time while seeking full-time employment.

Capital Services

In the CBO's revisions of its estimates of potential GDP between 2007 and 2014, changes to the contribution of capital account for one-third of the reduction in the level of potential GDP in 2017. However, the accumulation of capital services is largely determined through a

[3] See also Canon, Kudlyak, and Debbaut (2013).

highly endogenous process that is driven by changes in total output (GDP). Capital investment plunges during recessions in response to reduced demand and heightened uncertainty, but it will ultimately recover and grow over the long term in proportion to increases in the workforce and TFP, reflecting a very stable trend in capital intensity, the ratio of capital services to potential output.[4] The fall in the investment rate in recent years has slowed the growth of the capital input. It is recovering, and, with a lag, growth in the capital input will accelerate and return to trend.

Total Factor Productivity

In making its forecasts for future years, the CBO assumes that TFP will grow at 1.2 percent a year, the same rate of increase as was seen from 2004 to 2014, although much slower than the boom years after 1995. It is certainly possible that some of the sluggishness in TFP growth is the result of the recession, but it seems that the big issue is whether the long-term trend is slow, and we tackle that question in the next section.

Combined Output Effects

The CBO has revised down its estimate of the current potential output of the United States by 7 percent compared to the level that it anticipated in 2007, before the recession. It is striking, however, that only a small portion of the revisions, about one-fourth, is attributed to the direct effects of the recession and weak recovery. Instead, the bulk of the downward adjustment is attributed to a reassessment of prior trends (CBO 2014). The information and communication technologies (ICT)–based boom of the late 1990s is seen as initiating a wave of excessive optimism that led to the neglect of negative demographic influences on labor-force participation and a slowing of growth in productivity, problems that are now perceived as being evident prior to the recession. Reduced growth of potential

[4] Recent revisions to the national accounts resulted in a considerable broadening of the definition of capital to include research and development and other forms of intellectual property but without much impact on the trend in capital intensity. The CBO does not make a cyclical adjustment to its measure of capital services. While the actual use of capital services may vary greatly over the business cycle, there is no available measure of its utilization. Therefore, the computed volume of capital services already corresponds to its potential flow.

Table 3.1
CBO REVISIONS TO POTENTIAL GDP GROWTH ANNUAL % CHANGE

	2007 Projections		2014 Projections	
Contribution from	**2007–17**	**2013–17**	**2014–17**	**2018–24**
Potential hours	0.6	0.4	0.3	0.5
Capital services	1.1	1.1	0.8	1.0
Potential TFP	1.4	1.4	1.2	1.2
Total	3.1	2.9	2.3	2.6

SOURCE: CBO (August 2014).

labor and capital inputs each account for a third of the reduction, and about a fourth can be traced to a lower-than-expected growth of TFP. These revisions on the supply side of the economy have sharply altered perceptions of the amount of slack in the economy, cutting the shortfall of GDP relative to potential by more than 50 percent. However, they seem consistent with the recent rapid decline in the overall unemployment rate and the rise in capacity utilization in the industrial sector. As discussed above, the CBO's attribution of the revisions to a reassessment of prior trends is echoed in the research of others on changes in labor-force participation and TFP.

The CBO's reduction in the level of potential GDP also carries into the future because it has lowered its expectations of growth in potential output over a 10-year horizon (see Table 3.1). For the years of overlap between its 2007 projections and those of 2014, the growth of potential GDP in the nonfarm-business sector is cut back from 2.9 percent per year to 2.3 percent, with the decreases spread across labor hours, capital services, and TFP. The CBO projects a recovery in the last half of its projection period due to a modestly higher growth in factor inputs, but it maintains a reduced expectation for future growth in TFP.

Has the Rate of Technological Change Slowed?

As observed by Gordon (2012, 2014), productivity growth has been slow in the United States for many decades. In the historical data for the nonfarm-business sector used by CBO, the cyclically adjusted measure of TFP growth decelerated from an average of 1.9 percent per year in 1950–73 to only 1 percent in 1973–95. There was then a revival lasting up to 2004 that has been widely attributed to the explosive growth of ICT, and annual increases in TFP averaged 1.7 percent. However, in the 10 years after 2004, the CBO measure of TFP growth has again slowed to 1.2 percent, in part because the production of ICT products has been moved out of the United States. The latest CBO projections assume the 1.2 percent growth rate for TFP in future years. A comparable story emerges from the analysis of labor productivity as used by Gordon. The measures of labor productivity imply a larger post-1995 revival of annual productivity growth (relative to TFP), increasing by 1.3 percentage points above the prior average, but with a full reversion to the post-1973 rate after 2004.[5]

John Fernald (2014) adopts a position similar to Gordon based on his analysis of a detailed industry data set of the BLS. He argues that the ICT-dominated surge in TFP ended in 2004 and slowed substantially in the precrisis period of 2004–7. Thus, the slowdown is not a product of the recession. He also argues, as does Gordon, that the 1973–95 pace of productivity change is a reasonable expectation for the future. His analysis suggests that the slowdown is particularly marked in the ICT sector. Byrne, Oliner, and Sichel (2013) agree with Gordon and Fernald that there has been a substantial slowing of productivity growth, but they are a bit more optimistic about a partial recovery in the IT-producing industries and project growth in labor productivity within the nonfarm-business sector above 2 percent.

Jorgenson, Ho, and Samuels (2013) provide another perspective that is also more optimistic about the outlook for TFP growth, primarily because of continued strong gains in the IT-using industries. However, their overall projection of GDP growth is reduced by offsetting expectations of a substantial falloff in the rate of improvement in labor quality (an adjustment not included in the CBO methodology). Similarly, Baily, Manyika, and Gupta (2013) cite the development of a number of new technologies and emphasize the uncertainty involved in any projection of TFP.

The CBO's 2014 estimate of future TFP growth (1.2 percent) is significantly below its estimate as published in 2007 (1.4 percent), but it is still above the 1 percent average during 1973–95. If Gordon's

[5] The labor productivity measures reflect some of the strong cyclical variation in capital services.

suggestion that the ICT-driven revival was a transitory phenomenon and that we are reverting to the post-1973 era of smaller gains in productivity is correct, there is concern that the projections of future productivity growth by the CBO remain too high.

Mismeasurement of the Productivity Impact of Technology

In a 1988 paper, Baily and Gordon looked at the idea that mismeasurement might explain why "computers are everywhere except in the productivity statistics." The paper argued that real output growth in many industries, large and small, was poorly measured or not measured at all. Many other authors raised questions about data quality, and in the late 1990s, the three main U.S. statistical agencies together with the Sloan Foundation funded a large effort based at the Brookings Institution to identify the problems and find solutions. This work is reported in Triplett and Bosworth (2004), and it resulted in improvements in the quality of the data.

The economy may have moved in new directions since then, however, and so the statisticians are chasing a moving target. For example, much of search and social media is funded through advertising and is therefore counted as an intermediate good. Many innovations are designed to improve convenience (e.g., ride sharing with Uber), and the convenience factor is not counted in real output. One of the largest sectors in the economy is health care, where there has been a lot of innovation in medical procedures and devices and pharmaceuticals, but where productivity gains mostly are not measured.

It is difficult to assess the impact of high-technology companies, such as Apple Inc., on measured future productivity gains in the United States. Even if we assume that Apple's design innovations are the result of R&D work done in the United States, the products are produced abroad by foreign contract manufacturers. Apple will transfer its intellectual property as an export to a foreign subsidiary at something close to cost to avoid U.S. taxes and incorporate it in the wholesale value of an iPhone or equivalent product. When Apple brings the iPhone or equivalent back to the United States, its high retail price is matched by a similarly high import valuation to avoid U.S. taxes, implying a low margin on the retail sale. Thus, it is likely that Apple's reported contribution to U.S. gross domestic product is much smaller than its actual contribution. A large fraction of what is being produced in Cupertino, California, is attributed to a subsidiary in a low-tax jurisdiction.

It is possible, therefore, that the slowdown in productivity growth since the early 2000s coincides with a large increase in the mismeasurement of output and productivity. However, the evidence so far is not clear enough to provide a quantitative estimate of how large the mismeasurement may be, how rapidly it may have worsened over time, and whether there may be areas of overstatement as well as understatement of output growth.

Productivity and Wages: Is the W. Arthur Lewis Model Working in Reverse?

Real wage gains have been negligible over the past decade, and there has been a marked rise in inequality of earnings, with upper-income workers, especially those at the very top, receiving large income gains while lower-income workers have seen few gains or even declines after adjusting for inflation. One striking pattern in the data is that average real wage increases have been much slower than the growth of average labor productivity. The rise in earnings inequality, plus the slow growth of earnings, plus the increased share of profits in national income, has given rise to growing claims of unfairness. We do not have a full explanation of what is driving these economic trends, but there are some important aspects that can be clarified. In addition, we suggest a possible link between labor-market shifts and slow productivity growth.

The Link between Wages and Productivity Growth

For many years after World War II, the growth in average labor productivity was roughly matched by the growth in real wages, and both growth rates were strong. Growth slowed in the early 1970s, and there began a widening gap between wages and productivity. There are several reasons why the paths of wages and productivity may diverge. The first, and the one that has received the most attention recently because of the book by Thomas Piketty (2014), is that the share of output going to wages may vary over time. Piketty suggests that labor's share of income will gradually decline, and, in the U.S. data for the nonfarm-business economy, such a decline in the labor share has been evident since World War II. However, for most of the period, that was entirely due to an adjustment to the data to include the labor-type income of the self-employed.[6] There has been, however, a larger and more evident decline in labor's share since 2000, and whether this is a sign of a long-run trend or a transitory shift remains to be seen.[7]

A second reason for slow wage growth is the increase in the amount of total compensation going to benefits, primarily provisions for retirement and health insurance that are paid for through employers. Over the postwar period as a whole, there has been an enormous expansion of employer-funded benefits, but these costs have played a surprisingly minor role in the distinction between labor compensation and wages in recent years. In fact, the growth of take-home pay in nonfarm business has slightly outpaced that of hourly compensation since 1995 in part because of the movement away from employer-funded pensions.

The third source of divergence between wages and labor productivity is that real wages are usually calculated using the Consumer Price Index to adjust for inflation, but real output, the numerator of the productivity ratio, is calculated using a price index for the sector's output. And the two price series diverge substantially because workers consume goods and services such as housing and health care whereas the business sector produces a lot of electronics and other machinery. Consumer prices have risen faster than producer prices since the early 1970s. The productivity surge in the 1990s was led by very strong gains in the computer and semiconductor sectors and did not translate into an equivalently large decline in consumer prices.

The overall conclusion from these three points is that the main reason for the slow growth in real wages since the early 1970s has been the slow growth of productivity, exacerbated by even slower growth of productivity in the production of goods and services that make up the typical consumption basket. The size of the pie has not been increasing very fast.

[6] The income of the self-employed reflects a return on their invested capital as well as their own labor hours. The BLS imputes a wage rate equal to that of employees in their industry. Over the postwar era, the share of the self-employed in the workforce has slowly declined.

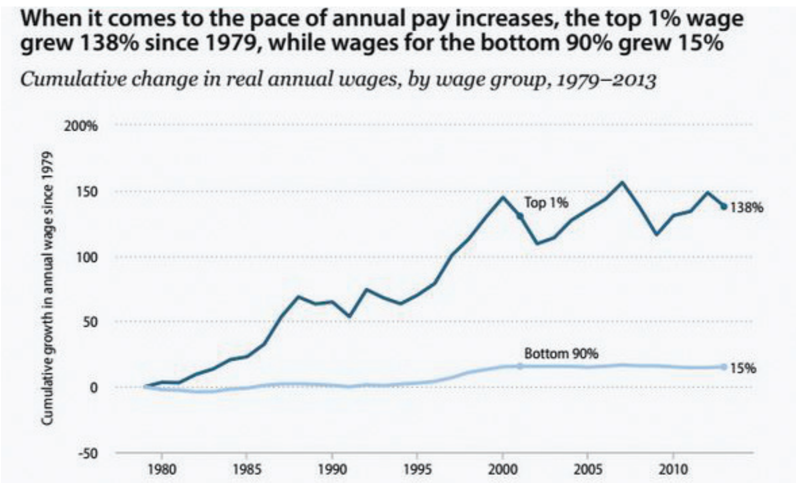
[7] In his ongoing research, Robert Z. Lawrence of Harvard has pointed out that the mechanism Piketty describes is one in which the capital share increases as a result of an increase in the capital–labor ratio interacting with an elasticity of substitution greater than unity. In fact, since 2000, the rate of capital accumulation has been weak and the growth in the capital–labor ratio has been very slow.

Superimposed on the slow growth of the pie have been the concerns about the distribution of the pieces of the pie. Piketty points to the increased profit share, but a bigger and more persistent problem has been the rise in wage–earnings inequality. As Figure 3.2 from the Economic Policy Institute shows, wages at the 99th percentile have grown much more rapidly than the wages of the bottom 90 percent.

In summary, the overall pace of technological change has been fairly slow, and the change that has taken place is strongly biased, favoring workers who cannot be replaced by automation or who are complementary with this form of capital and technology. International trade also plays an additional role where competition from low-wage countries reinforces the shift in labor demand away from traditional production-worker jobs.[8]

We would like to build on and expand on this explanation in two ways. The first is a descriptive extension, pointing out how the pattern of recent economic growth is a remarkable turnaround from

Figure 3.2



SOURCES: Economic Policy Institute (EPI) analysis of data from Kopczuk, Saez, and Song (2010) and Social Security Administration wage statistics. Reproduced by EPI from Figure F in Bivens et al. (2014).

[8] See the discussion in Baily and Bosworth (2014).

the classical view of economic development presented in the 1950s by W. Arthur Lewis. The second extension takes off from the literature in labor economics, looking at how a shift in business strategies has impacted wages and productivity.

The W. Arthur Lewis Model and the Experience of Mexico

In a 1954 article, Nobel Prize winner W. Arthur Lewis used a dual-sector model to formulate what became a standard framework for understanding economic development. Developing countries typically have a modern sector that employs production processes similar to those in higher-income developed countries, but there is also a large subsistence sector, dominated by agriculture, that has "excess labor"—that is, there are more workers than can be employed productively. Development proceeds when the modern or industrial sector expands and attracts workers from the agricultural villages into the town and cities. The modern sector is more productive, so average productivity rises as that sector expands. And productivity in the subsistence sector also rises as the excess labor is drawn off. This model also helps explain how the Industrial Revolution transformed today's developed economies in the 19th or 20th centuries.[9]

In principle, the pattern described by Lewis should continue until the whole economy is developed and production processes are at or near global best practices. In practice, some economies seem to have hit a wall before they have completed the development process. Consider, for example, the case of Mexico.[10] Mexico has a highly developed modern sector, including the auto industry and big-box retailing. Foreign direct investment has been a contributor to growth in the modern sector, but there are also successful domestic companies using close to best-practice business models. The free-trade agreement, NAFTA, also encouraged the growth of this modern sector. At the same time, Mexico has a large and growing informal or traditional sector. This low-productivity sector includes some parts of agriculture but is mostly concentrated in urban areas and consists

[9] Denison (1967) shows how the movement of labor out of agriculture explained much of the rapid growth of Japan in the 1960s.

[10] The discussion of Mexico and the data cited here are taken from McKinsey Global Institute (2014).

of such activities as street vendors and handicraft manufacturing, as well as small restaurants and other service establishments.

The proportion of employment in firms with fewer than 10 employees rose from 39 percent to 42 percent between 1999 and 2009. Average labor productivity in the modern sector rose by 5.8 percent a year during 1999–2009 while *declining* at 6.5 percent a year in traditional firms. Average real wages in Mexico have declined, reflecting the productivity weakness in the traditional sector. Mexico is thus a dual economy. Any two-sector model of the economy is, of necessity, simplistic, and of course there are very large differences between the United States and Mexico, but there may be a lesson in the Mexican experience for the American economy.

A Dual Economy in the United States?

In the heyday of the U.S. Industrial Revolution, the industrial and commercial sector of the economy was growing rapidly and increasing its demand for labor, pulling workers off the farms and pulling millions of immigrants into the economy. Wages were low in the early stages of the revolution, and working conditions were terrible, but wages were high enough to attract people out of agriculture and traditional activities. As excess labor ran out, the demand for workers continued to grow and drive up wage rates, creating a broad middle-class prosperity.

At some point in the 1960s or 1970s, this process changed. The "modern" sector continued to prosper, but it was no longer increasing its demand for labor at the same rate, particularly its demand for workers lacking a college education or other strong, marketable skills. Output and productivity within this sector continued to rise, but an increasing proportion of the overall workforce was pushed into low-productivity activities, just as has happened in Mexico. Some observers see low average-wage and productivity growth and claim innovation has slowed. What has actually happened, though, is that productivity has continued to increase in the modern sector, but average productivity growth in the overall economy has not because so much employment has shifted to low-productivity jobs. One indicator of this is provided by a study of U.S. multinationals published by the McKinsey Global Institute in 2010 that found that productivity growth in these companies, measured by output per hour, had risen at 3.5 percent a year from 1990 to 2000, compared to only 1.5 percent in other firms. On the other hand, employment had risen by only 0.7 percent a year in multinationals and by 1.5 percent in other firms.[11]

One of the important differences between Mexico and the United States is that many of the low-wage, low-productivity jobs are not in the informal sector in the United States. Walmart and McDonald's are both highly efficient global companies that make extensive use of technology to run their businesses. But they have determined that it provides cost advantages to build efficiencies into the production process and use low-wage workers to fill the majority of their jobs. The duality is taking place within these firms, as managers and executives, piloting the global growth of the corporations, are paid high incomes but the bulk of the employees are not. These two companies are often singled out, but they are not unusual. In industries such as retail, lodging, and fast food, the great majority of jobs are low skill and low wage. Even banks have lowered costs by hiring lower-wage tellers and building most of the knowledge into the computer systems. Walmart experiences close to 50 percent annual turnover of its sales clerks, but the turnover of bank tellers is similar.[12] So what corresponds to the informal sector in the U.S. economy consists in part of people working in something close to an actual informal setting, such as mom-and-pop establishments or pickup work. But more importantly, it consists of those working for large companies in activities that have been deskilled, in jobs that provide little training, and in jobs where workers stay only for a short time and hence gather little on-the-job experience.

The idea that machines can replace skilled workers is hardly new; it goes back to the early years of the Industrial Revolution, when the Luddites broke weaving machines. What is different in the past 30 or 40 years in the U.S. economy is that the reduction of jobs as a result of technology in one firm or industry has not been followed by the opening up of well-paid jobs in other parts of the economy, or at least not enough such jobs have opened up. The process of economic development no longer works to raise wages across the board. As a result, the economy has become dualistic, with innovation benefiting those with strong market-oriented skills, the owners of corporate

[11] McKinsey Global Institute (2010).

[12] For more on Walmart's turnover, see Buchanan (n.d.). The figure for bank-teller turnover was given to the author by the chief executive officer of a large regional bank.

equities, and those who own successful private companies, but not the broad workforce.[13]

In the Lewis model, a country starts its path to economic development with surplus agricultural labor, which is then pulled away by strong demand in the modern sector, with the shift in labor from a low-productivity sector to a high-productivity sector contributing to the average growth of productivity. In the current U.S. economy, a larger and larger share of employment is concentrated in high-turnover, low-productivity activities, pushing down average productivity growth as well as wages. Excess labor is being absorbed into underemployment and of course some workers, faced with lousy choices, end up unemployed, out of the labor force, or in the criminal-justice system.

The High Road and the Low Road in Employment Strategy

Alfred Marshall discussed the concept of efficiency wages early in the 20th century, but the more recent theories of efficiency wages were developed by writers such as Stiglitz (1974) and Salop and Salop (1976) in an effort to understand why wages in a market economy do not fall to the level that clears the market. There always seem to be unemployed workers willing to work at the prevailing market wage but unable to find jobs. The models postulate that firms will not pay the lowest possible wage rate necessary to attract job applicants because they want to attract workers with the skills they need, because they want to encourage their workers to value the jobs that they have and not shirk, or because they wish to reduce turnover among existing employees. This last issue is particularly important if firms need to invest in training their workforces.

Labor economists talk about companies that take the "high road" in employment strategy and those that take the "low road." High-road employers aim to train the workers, pay them a wage consistent with retention, and create a career path where workers can move up in the company. Companies that take the low road, on the other

[13] We acknowledge the important paper by Michael Spence and Sandile Hlatshwayo (2011). They also present a two-sector view of the economy based on industries subject to global competition and those not. This discussion owes a debt to their paper, but there are differences in how they divide the economy into two sectors. They divide the economy based on tradable and nontradable sectors, whereas we see skill-biased technology as the main driver, although trade is a factor also.

hand, pay close to minimum wages, provide very little job training, and expect that a high fraction of workers will quit after a short time on the job.

One hypothesis to help explain both the widening of the wage distribution and the sluggishness of productivity is that the fraction of employers taking the low road may have increased. Empirical evidence is needed to make a serious case in this regard, but there are some a priori reasons why this may be the case. First, there have been institutional changes in the workforce, with a much smaller proportion of workers being unionized and the threat of unionization being much lower. This means that the low road is more feasible for companies as a sustainable strategy. Second, the level of competitive intensity in the economy has been greater as best-practice companies have expanded nationwide, driving out some traditional employers. Also, global competition has forced companies to make cost reductions. And the third factor is that technology has changed in ways that drive companies onto the low road.

Skill-Biased Technical Change and the Low-Road Strategy

Some years ago, the German retailer Aldi in its operations in Germany required that all of its sales clerks memorize the prices of its products. The clerks could see what the customer was buying and enter the price into the register without looking for the product label, thus speeding up checkout. U.S. retailers, on the other hand, were early adopters of scanning technology using bar codes, which meant that clerks no longer had to enter prices into the register; moreover, inventory management was simplified because all sales were in the company computers. The spread of scanning technology has meant that virtually all retailers in advanced economies now use scanners. The technology has encouraged retailers to follow the low-road employment strategy, eschewing trained and skilled workers in favor of lower-cost workers. This example is just the tip of the iceberg in terms of how technology is de-skilling jobs.

Hence, if the process of development described by W. Arthur Lewis is running in reverse, it is because the nature of technology and innovation has changed in the computer and electronic age, in a way that pushes more and more workers into low-skill activities. It encourages low-road policies, causes an increase in the disparity of earnings, and, as wages have fallen, it has increased profits.

A key question at this point is whether or not the hypothesis can also explain slow productivity growth. On the face of it, one can argue that it would not, because companies like McDonald's and Walmart are highly efficient and have forced other companies to raise their own game to compete. And despite some faltering in the last few years, these and similar companies have been very profitable. Following the low road can be combined with high throughput, where a very large number of meals are served or a very large volume of goods is retailed.[14]

The counter to this is that based on value added per hour, the low-road companies do not have high productivity, and value added per hour is the measure of productivity that aggregates to the BLS estimates of output per hour. Moreover, whatever productivity gains accrued from shifting to the low-road strategy may have been a one-time event. Productivity surged in the late 1990s and into the early years of this century as many companies restructured to cut costs. Because that transition took place, longer-run negatives to the low-road strategy are now appearing:[15]

[14] Walmart recently announced it was raising wages of its employees to improve morale. See http://finance.yahoo.com/news/pay-hike-good-news-wal-144425808.html.

[15] Labor markets in Japan and in Europe have been undergoing major changes designed to make their workforces more flexible. In particular, whereas the traditional employment arrangements in these economies involved long-term employment, there has been increased use made of short-term labor contracts, and this shift has prompted researchers in these economies to examine the productivity consequences. We describe four of these studies. Aoyagi and Ganelli (2013) argue in an International Monetary Fund staff paper that the path to stronger growth in Japan requires overcoming the problems that have been created by short-term employment contracts. These have reduced the amount of training provided to workers, reduced the morale of the workforce, and discouraged workers from working hard because there is no return to effort in terms of long-run employment. Lotti and Viviano (2012) examine the impact of short-term employment using a panel data set of Italian companies over the period 1999 to 2010, and they report a significant negative effect of fixed-term employment on productivity compared to permanent employment. Dolado and Stucchi (2008) look at a sample of Spanish companies over the period 1995 to 2005 and conclude that work effort and productivity are strongly adversely affected if workers do not have the option of converting temporary work contracts into permanent contracts. Fukao and Kwon (2006) also look at Japan and find in a matched data set of employers and employees that part-time workers have 75 percent of the productivity of full-time workers, controlling for other characteristics. No doubt the detailed conclusions of these cited studies can be questioned, but the results are consistent with the conclusions of the efficiency-wage literature, one that has been explored empirically in the United States. And the findings are almost self-evident. Workers with very little training or on-the-job experience and relatively low motivation are going to be less productive.

1. There is a long-run corrosive effect of a labor market in which many of the workers move from one short-term boring job with low pay to another such job. Motivation to work hard and perform well is eroded.
2. Because wages are very low, companies choose to operate very long hours and have staff in occupations with very marginal impact. Grocery stores, drug stores, restaurants, and fitness centers stay open until midnight, or even all night. People are hired as greeters, whose only job is to stand by the door saying, "Welcome to Walmart" or "Welcome to CVS." Long hours do provide convenience to consumers, but the convenience value of the long hours is not measured.
3. The chronic and very large trade deficits experienced by the United States have reduced employment in manufacturing and other tradable-goods sectors, pushing workers into lower-productivity jobs in service industries.
4. Once a company has taken the low road, it is dependent on top-down innovation, driven by technology and design. In the Toyota production system, many productivity gains are driven by incremental changes suggested by employees. If workers do not have a stake in their companies, they have no incentive to suggest improvements and may not stay long enough to figure out what might be changed. One important source of productivity improvement disappears with the low-road approach.

A caveat: It is an overstatement to say that the middle of the labor market has disappeared. There are workers with less than a college education who make good incomes as auto mechanics, plumbers, heating and air conditioning engineers, welders, carpenters, and so on. As noted earlier, talking of a dual economy is oversimplified, and moreover, it is puzzling why more young people do not seek out the skills that will allow them to earn a decent living. Despite this caveat, concerns about the quality of jobs in the U.S. economy are large and real.

Conclusion

We find that the impact of the recession on long-term growth prospects looks modest. There has been a sharp decline in the labor force, but three-quarters of this is demographic, and the remainder should be eliminated in the next several years. Capital investment has been weak, but that seems to be mostly because of a lack of investment opportunities. It is both a consequence as well as a cause of slow productivity growth.

TFP growth has been slow since around 2004, and we explore three possible reasons for this. First, it may be that technological opportunities are disappearing. Second, the nature of technological change may be such that current estimates of output and TFP growth understate the effects of new products and services. Third, technological opportunities may still be strong, but they cause a skill bias in labor demand. We suggest that this last explanation can result in a dual labor market with an expanding group of low-skill workers in lousy short-term jobs. Average labor productivity at any moment is the average of the labor productivity of the high-wage, high-productivity workers and the low-wage, low-productivity workers. As has happened in Mexico, average productivity in the United States may be dragged down by the share of the workforce in low-productivity activities.

In the *New York Times*, David Brooks (2015) contrasts the conservative approach of Marco Rubio to improving growth with the liberal view of the Balls-Summers commission.[16] This paper is not directed at policy solutions, but it suggests that incentives that shift firms away from low-road to high-road strategies may be helpful. Despite Europe's current problems, it is notable that German manufacturing companies use a high-road strategy, pay much higher wages than do U.S. companies, and run a very large trade surplus in contrast to our large deficit.[17]

[16] For more on the Balls-Summers commission, see Summers and Balls (2015).

[17] The very recent sharp decline in the euro has made German wages look lower. The statement about high wages and trade surpluses has been true for many years.

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SECTION TWO

THE FUTURE OF INNOVATION

4. The Turtle's Progress: Secular Stagnation Meets the Headwinds[1]

Robert J. Gordon[2]

Distinguishing between Secular Stagnation and Slow Long-Term Growth

No single image captures the present concern about secular stagnation and slowing long-term economic growth better than the *Economist* cover of July 19, 2014, showing a frustrated jockey dressed in the colors of the American flag frantically trying to get some movement from the gigantic turtle that he is riding. U.S. real gross domestic product (GDP) growth has grown at a turtle-like pace of only 2.1 percent per year in the last four years, despite a rapid decline in the unemployment rate from 10 to below 6 percent. Almost all of that improvement in the unemployment rate has been offset by an unprecedented decline in labor-force participation, such that the ratio of employment to the working-age population has hardly improved at all since the trough of the recession.

I have recently (2014a) restated the case for slow growth over the long run of the next 25 to 40 years. At the same time, Larry Summers (2013) has signaled his alarm about a return of "secular stagnation," a term associated with a famous 1939 paper by the Harvard economist Alvin Hansen. However, Summers and I are talking about different aspects of the current American growth dilemma. His analysis concerns the demand side, "about how we manage an economy in which the zero nominal interest rate is a chronic and systemic

[1] This chapter originally appeared in Coen Teulings and Richard Baldwin, eds., *Secular Stagnation: Facts, Causes and Cures* (London: Centre for Economic Policy Research, 2014), pp. 41–59.

[2] Robert J. Gordon is a professor of economics at Northwestern University. Burke Evans contributed the graph and incisive suggestions about the exposition.

inhibitor of economic activity, holding our economies back below their potential."[3] In contrast, my version of slow future growth refers to potential output itself.

As the U.S. unemployment rate declines toward the normal level consistent with steady nonaccelerating inflation, by definition, actual output catches up to potential output. I have provided (2014b) a layman's guide to the numbers that link the performance of real GDP and the unemployment rate and have concluded that U.S. potential real GDP over the next few years will grow at only 1.4 to 1.6 percent per year, a much slower rate than is built into current U.S. government economic and budget projections. My analysis suggests that the gap of actual performance below potential that concerns Summers is currently quite narrow and that the slow growth he observes is more a problem of slow potential growth than a remaining gap.

Hansen's 1939 version of secular stagnation was written prior to the invention of the concept of potential GDP and indeed of real GDP itself.[4] Because there was no comprehensive measure of real economic activity, there was no notion of aggregate productivity or its growth rate. When we look at today's statistical rendering of the American economy in the late 1930s, we see that Hansen was writing about an economy with healthy potential GDP growth but a large gap of roughly 20 percent separating the levels of actual and potential GDP.[5]

Some have dismissed Hansen's concerns by pointing to the rapid growth in productivity that was occurring as he wrote, during what Alexander Field (2003) has called the 20th century's "most technologically progressive decade." Some optimistic writers have pointed to the upsurge in productivity growth that occurred in the 1930s and 1940s as offering the possibility that history might repeat itself and

[3] These are the final words from the transcript of his speech given at the International Monetary Fund. See Summers (2013).

[4] The term "secular stagnation" was introduced not in Hansen's presidential address but rather four years earlier in Hansen (1934, p. 19).

[5] Current NIPA data for nominal GDP register $104.6 billion in 1929, $57.2 in 1933, and $87.4 in 1938. Gordon and Krenn (2010) estimate the GDP gap for 1938:Q4 to be 23.1 percent, implying that nominal potential GDP was $113 billion in 1938. Potential GDP grew between 1928 and 1941 at 3.1 percent per year, and labor productivity grew at 2.7 percent per year, more than double the rate achieved in 2004–14.

lead to faster productivity growth over the next two decades than even the productivity heyday of 1996–2004.[6]

The reality of 2014 is far grimmer than what faced Hansen's America of 1938, because America was about to receive a succession of lucky breaks that utterly transformed late 1930s gloom into postwar prosperity. Hitler's invasion of Poland created a doubling of export orders in the winter of 1939–40. After the fall of France, the U.S. government pushed the ignition switch on the Arsenal of Democracy, and before Pearl Harbor, the share of total government spending in GDP had doubled. Real GDP grew at an annual rate of 12.8 percent between 1939:Q4 and 1941:Q4. By 1944, real GDP had doubled from the level of 1939. Most amazingly, the economy did not slide back into depression conditions when this huge dose of fiscal stimulus was removed; labor productivity was actually higher in 1950 than in 1944.

The Demise of Growth Originates in Headwinds, Not Technology

My forecast of growth over 25 to 40 years is measured from 2007, not from now. The sources of slow growth do not involve technological change, which I assume will continue at a rate similar to that of the last four decades. Instead, the source of the growth slowdown is a set of four headwinds already blowing their gale force to slow economic progress to that of the turtle. These four barriers to growth are demographics, education, income inequality, and government debt. These will reduce growth of real GDP per capita from the 2.0 percent per year that prevailed during 1891–2007 to 0.9 percent per year from 2007 to 2032. Growth in the real disposable income of the bottom 99 percent of the income distribution is projected to be an even lower 0.2 percent per year.

While many authors acknowledge the demographic headwind, its long-term quantitative impact on economic growth remains

[6] Syverson (2013, Chart 1) cleverly displays the level of labor productivity with two horizontal axes, one extending from 1890 to 1940 and the other aligned 80 years later to extend from 1970 to 2020. This 80-year displacement implies a parallel between 1932 and 2012 and overtly suggests that productivity growth will speed up radically after 2012 as it did after 1932. He ignores the fact that much of the upsurge of productivity growth after 1932 was cyclical and related to the doubling of real GDP between 1939 and 1944.

open to debate. By definition, growth in output per capita equals growth in labor productivity times growth in hours per capita. The slowdown in productivity growth that began 40 years ago was partly offset between 1972 and 1996 by an increase in the labor-force participation rate of 0.4 percent per year, as females and Baby Boom teenagers entered the labor force. In contrast, during 2004–14, the participation rate declined at an annual rate of 0.5 percent, and over the shorter 2007–14 interval at an annual rate of 0.8 percent. This transition from a 0.4 percent *increase* to a 0.8 percent *decline* accounts for a 1.2 percent reduction in the growth of per capita real GDP for any given growth rate of labor productivity.

Recent research (Hall 2014) has shown that about half of the 2007–14 decline in participation is due to the aging of the population as the Baby Boom generation retires. The other half is due to declining participation within age groups, due in part to weak economic conditions. Even if the decline in participation slows from 0.8 to 0.4 percent per year, the portion attributable to Baby Boom retirement, that still is enough to make it impossible for real GDP per capita to match productivity growth.

The second headwind is education. Throughout most of the 20th century, rising high-school completion rates permanently changed the productive capacity of American workers, but this transition was over by 1970. Further increases in high-school completion rates are prevented by dropping out, especially of minority students, as the United States slides to number 16 rank for secondary-school completion in an international league table among developed countries. Similarly, the United States is number 16 in college completion rates, and there are new problems—over $1 trillion in student debt combined with the inability of 40 percent of college graduates to find jobs requiring a college education, spawning a new generation of indebted baristas and taxi drivers.

The third headwind is income inequality that continues to grow inexorably as salaries for chief executive officers and celebrities march ever upward, augmented by the creation of trillions of dollars in stock-market wealth. Below the 90th percentile, corporations are working overtime to reduce wages, reduce benefits, convert defined-benefit pension plans to defined contribution, and use Obamacare as an excuse to convert full-time jobs to part-time status.

The fourth headwind is the predicted upward creep in the ratio of federal government debt to GDP. The official Congressional Budget Office (CBO) data greatly understate the gravity of the problem, because the CBO estimate of future potential GDP growth is out of touch with reality. Because potential real GDP growth is already much slower than the CBO estimates (Gordon 2014b), future tax revenue will grow more slowly, boosting the debt in the numerator of the debt/GDP ratio, while the denominator will grow more slowly, thus further increasing the ratio. The federal debt/GDP ratio could well reach 150 percent by the late 2030s, and this does not take into account the apparently intractable pension burdens in some of the largest state and local governments.

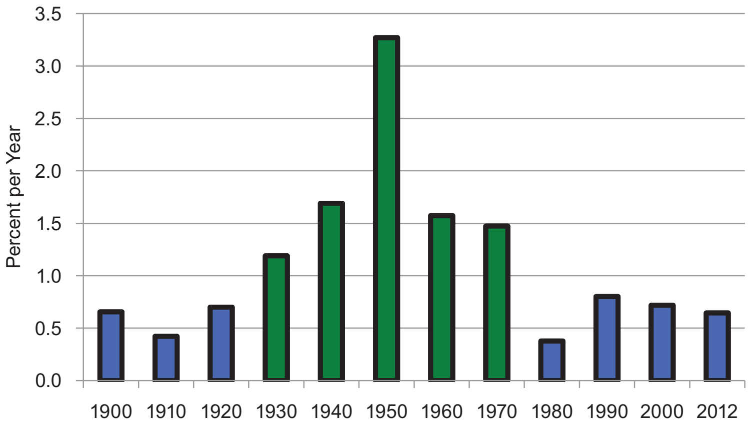
For the disposable (after-tax) incomes of the bottom 99 percent, it is hard to find any room for growth at all. Indeed, official measures of median wage and household income have not grown for several decades. While these measures may understate income growth, my exercise in taking the historical record of growth of real GDP per capita and then subjecting it to "an exercise in subtraction" avoids the problem that some of the median wage and household income data exclude elements that are included in the data on GDP and personal disposable income.

Nobody Debates the Headwinds; Instead, They Debate Technological Progress

My forecast of slow growth after 2007 does not rely on any slowing of future technological change. My "exercise in subtraction" deducts 1.2 percent from the realized 1891–2007 per capita output growth rate of 2.0 percent for the combined impact of the four headwinds. Then, I deduct an additional 0.6 percent for the fact that productivity change slowed markedly from the 80 years before 1972 to the 40+ years since 1972. *In my numbers, there is no forecast of a future technological slowdown: productivity growth adjusted for educational stagnation is predicted to be just as fast during 2007–32 as during 1972–2007.*

Critics of my growth forecasts have largely ignored the fact that I am not suggesting that the pace of innovation will slow in the future compared to the achievements of 1972–2014. What the *Economist* cover called today's "loss of oomph" in the U.S. economy occurred after 1972—that is, after the first century of implementing

Figure 4.1
ANNUAL GROWTH RATE OF TOTAL FACTOR PRODUCTIVITY FOR 10 YEARS PRECEDING YEARS SHOWN, YEARS ENDING IN 1900 TO 2012



the rainbow of benefits from the inventions of the Second Industrial Revolution. In the early postwar years, the spread of air conditioning, commercial air travel, and the interstate highway system represented the final implementation of technologies invented in the 1870s. After 1972, the slowdown was visible in the data and has continued to the present.

For decades, macroeconomists struggled to understand the post-1970 productivity-growth slowdown. But, in fact, our entire generation has been asking the wrong question. Instead of wondering why there was a productivity-growth slowdown after 1972, we should have asked, "Can we explain the productivity miracle that occurred in the U.S. economy between 1920 and 1970?" While I join most analysts in preferring to compare productivity-growth data between years when unemployment and utilization were "normal," nevertheless, it is interesting to look at the raw data for each of the 12 decades since 1890, as in Figure 4.1. Any techno-optimist must look at this history with dismay. The future is not going to be better than the past, because the economy during 1920–70 achieved growth in total factor productivity (TFP) of a different order of magnitude in these "green" decades than during the "blue" decades before 1920 and since 1970.[7]

A debate has raged over the past two years about the future of economic growth: will it speed up or slow down? The case for a revival in growth is made most emphatically by two MIT economists, Erik Brynjolfsson and Andrew McAfee (2013), and by my Northwestern colleague Joel Mokyr (2014). The techno-optimists focus entirely on their hopes and dreams of unprecedented future breakthroughs in technology that center on the benefits of artificial intelligence, big data, small robots, medical miracles, and driverless cars and trucks. They ignore the headwinds and thereby have nothing to say about the core of my case that future disposable-income growth for the bottom 99 percent will be slower than in the past, a slowdown that already began years ago when the headwinds began to gain momentum.

These techno-optimist forecasts are useful only along one dimension. They give us hope that innovation might proceed at the same pace in the next few decades as in the last four. Yet they are utterly unconvincing that the pace of technological change will be *faster* over the next 25 years than over the last 40. Consider what they are up against that happened within the last 40 years since 1972: the mainframe era, which eliminated routine clerical jobs of endlessly retyping contracts, bills, and legal briefs; the invention of the personal computer, which allowed many professionals to write their papers without the aid of a secretary; the invention of game-changing technologies in the retail sector including the ATM machine, barcode scanning, self-checkout, and airline automated check-in kiosks; Amazon and e-commerce; Wikipedia and the availability of free information everywhere; the obsolescence of the hard-copy library catalog, the auto-parts catalog, the print dictionary, and the encyclopedia.

The pessimism in my forecasts of future economic growth is based on the headwinds, not a faltering of technology. I am dubious that

[7] TFP is defined as a weighted average of the ratio of output to labor input and the ratio of output to capital input, where both types of input are adjusted for quality changes. The TFP data displayed in Figure 4.1 are derived from scratch in Chapter 10 of my 2015 book. They combine labor and GDP data from the Bureau of Economic Analysis, Bureau of Labor Statistics, and Kendrick (1961), but they are also revised to change the concept of capital input to allow for variable retirement ages and to include certain types of government-financed capital input.

the nirvana of artificial intelligence, big data, robots, driverless cars, and so on will match the achievements enumerated above of the last 40 years. By basing my productivity forecast on a continuation of the 1972–2014 pace of innovation, I am deliberately suppressing my skepticism.

The techno-optimists differ in the nature of their concerns. Brynjolfsson and McAfee (2013) are admirable in their social concern that their abundant robots and big data will eliminate millions of jobs. Mokyr (2014) is not interested in jobs or headwinds. He predicts hypothetical future breakthroughs without any contact with the historical data, a remarkable position for an economic historian. He does not appear to care about the drama shown in Figure 4.1 of the TFP speedup during the 1920–70 period and its subsequent relentless slowdown.

Mokyr's sole comment about the headwinds (2014, p. 14) is that the unprecedented decline in the labor-force participation rate is partly offset by an increase in leisure. However, we have long known that leisure time during the workweek experienced by the unemployed or by those who would prefer to work has far less value than leisure time on weekends and during vacations. Labor-force participation has been declining in large part because many people are forced to retire without adequate finances and others give up looking for jobs after a desperate and endless search. He punctuates his dismissal of declining hours per capita with a remarkable quote: "But it may well be that a leisurely life is the best 'monopoly profit.'" He forgets his history: from the standpoint of the increasing marginal disutility of work, the real welfare-enhancing transition involving leisure occurred in the first half of the 20th century when the 60-hour manufacturing workweek of 1900 fell to 40 hours per week by 1950.[8]

The optimists, Brynjolfsson and McAfee and Mokyr, share a common reaction to any display of historical productivity data such as that contained in Figure 4.1. They claim that GDP is fundamentally flawed because it does not include the fact that information is now free due to the growth in Internet sources such as Google and

[8] Mokyr's claim that valuable leisure time partly or entirely offsets the lost income of the unemployed (and of those out of the labor force who would prefer to work) is sharply contradicted by a recent survey of the emotional well-being of the unemployed during the recent recession and slow recovery. See Krueger and Mueller (2011).

Wikipedia. A complementary statement is that numerous items have disappeared from GDP because they are already provided for free with a smartphone: not only the print dictionary or encyclopedia, but the music-playing capability that makes the separate iPod obsolete, the restaurant locator that makes the print Zagat guide obsolete, the growth in companies such as Uber and Lyft that may make the urban taxicab obsolete, and many more.

Two responses are appropriate about the unmeasured GDP made possible by the smartphone. The most obvious is that TFP growth sagged decades before the popularization of smartphones and the Internet. The most important event of the digital age was the marriage of personal computers and communications in the mid- to late 1990s in the form of the Internet, Web browsing, and email. Many of the sources of consumer surplus and free information were established more than a decade ago, including Amazon in 1994 and Google in 1998, as well as Wikipedia and iTunes in 2001. While progress has continued in the past decade with smartphones and Gmail, Google Maps, and other applications, these innovations are second-order inventions compared to the great marriage of computers and communications of the late 1990s, and the slow growth of TFP reflects that.

The much more important response is that GDP has *always* been understated. Henry Ford reduced the price of his Model T from $900 in 1910 to $265 in 1923 while improving its quality. Yet, autos were not included in the Consumer Price Index until 1935. Think of what GDP misses: the value of the transition from gas lights, which produced dim light and pollution and were a fire hazard, to much brighter electric lights turned on by the flick of a switch; the elevator, which bypassed flights of stairs; the electric subway, which could travel at 40 mph compared to the 5 mph of the horse-drawn streetcar; the replacement of the urban horse by the motor vehicle, which emitted no manure; the end of disgusting jobs for human beings required to remove the manure; the networking of the home between 1870 and 1940 by five new types of connections (electricity, telephone, gas, water, and sewer); the invention of mass marketing through the department store and mail-order catalog; and the development of the American South made possible by the invention of air conditioning.

Perhaps the most important omission from real GDP was the conquest of infant mortality, which by one estimate added more unmeasured value to GDP in the 20th century, particularly its first half, than all measured consumption (Nordhaus 2003). The list goes on. The invention of air conditioning and commercial air travel may have created more consumer surplus for more people than the provision of free information over the Internet.

While Mokyr is not concerned about the destruction of jobs implied by his hypothetical technological revolution, Brynjolfsson and McAfee are overly worried because they are too optimistic about the future reach of robots into the vast American service sector. Retail supermarkets are in stasis: the one-time benefit of the bar-code scanner 30 years ago has not changed the need for a human checkout clerk, and supermarket shelves are still restocked by humans, not robots. The higher-education sector has vastly inflated its costs by adding layers of administration without changing the nature of instruction. One wonders why the United States needs 97,000 bank branches, but the 1977 invention of the ATM machine has apparently not eliminated them.

The Future of Growth in the United States

Lawrence Summers's "secular stagnation" concern with the inability of policymakers to close the gap between actual and potential real GDP is almost obsolete because the gap is steadily shrinking. Now is the time to start trying to understand why the future pace of potential real GDP appears to be so slow and whether anything can be done about the headwinds, particularly demography, inequality, and debt, that drag down income growth for the bottom 99 percent so far below the slowing rate of overall growth. The techno-optimists are whistling in the dark, ignoring the rise and fall of TFP growth over the past 120 years. The techno-optimists also ignore the headwinds, which seems ostrich-like in their refusal to face reality.

The *Economist* of July 19, 2014, got it right. America is riding on a slow-moving turtle. There is little that politicians can do about it. My standard list of policy recommendations includes raising the retirement age in line with life expectancy, drastically raising the quotas for legal immigration, legalizing drugs and emptying the prisons of nonviolent offenders, and learning from Canada how to finance higher education. The United States would be a much better place with a medical system as a right of citizenship, a value-added tax to pay for it, a massive tax reform to eliminate the omnipresent loopholes, and an increase in the tax rate on dividends and capital gains back to the 1993–97 Clinton levels.

But hypothetical legislation, however politically improbable, has its limits. The headwinds that are slowing the pace of America's future economic growth have been decades in the making, entrenched in many aspects of our society. The reduction of inequality and the eradication of roadblocks in our educational system defy the cure-all of any legislation signed at the stroke of a pen. Innovation, even at the pace of 1972–2014, cannot overcome the ongoing momentum of the headwinds. Future generations of Americans who by then will have become accustomed to turtle-like growth may marvel in retrospect that there was so much growth in the 200 years before 2007, especially in the core half century between 1920 and 1970 when America created the modern age.

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5. Computing Bounty: GDP and Beyond[1]

Erik Brynjolfsson and Andrew McAfee[2]

Computing Bounty

> *"Most economic fallacies derive from the tendency to assume that there is a fixed pie, that one party can gain only at the expense of another."*
>
> *—Milton Friedman*

Each day, government agencies, think tanks, nongovernmental organizations, and academic researchers generate more statistics than any person could read, let alone absorb. On television, in the pages of the business press, and in the blogosphere, a chorus of analysts debate and predict trends in interest rates, unemployment, stock prices, deficits, and myriad other indicators. But when you zoom out and consider trends over the past century, one overwhelming fact looms above all others: overall living standards have increased enormously in the United States and worldwide. In the United States, the rate of gross domestic product (GDP) growth per person has averaged 1.9 percent per year going back to the early 1800s.[3] Applying the rule

[1] This chapter originally appeared in Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* (New York: W. W. Norton, 2014) pp. 97–124.

[2] Erik Brynjolfsson is a professor of management at the MIT Sloan School of Management and director of the MIT Initiative on the Digital Economy. Andrew McAfee is codirector of the MIT Initiative on the Digital Economy.

[3] While the rate has fluctuated with recessions, over longer periods it has been remarkably steady. In fact, in 1957, the economist Nicholas Kaldor summarized what was known about economic growth at the time in a classic article: Kaldor (1957). His observations, including the relatively constant growth rates of key variables, such as wage growth and the amount of capital per worker, came to be known as the "Kaldor Facts."

of 70 (the time to double a value is roughly equal to 70 divided by its growth rate), we see that this was enough to double living standards every 36 years, quadrupling them over the course of a typical lifetime.[4]

This increase is important because economic growth can help solve a host of other challenges. If GDP of the United States grows just 1 percent faster each year than currently projected, Americans would be five trillion dollars richer by 2033.[5] If GDP grows just 0.5 percent faster, the U.S. budget problem would be solved without any changes to policy.[6] Of course, slower growth would make it significantly harder to close the deficit, let alone increase spending on any new initiatives or cut taxes.

Productivity Growth

But what drives increases in GDP per person? Part of it comes from using more resources. But most of it comes from increases in our ability to get more output from the given level of inputs—in other words, increases in productivity. (Most commonly, this term is used as shorthand for "labor productivity," which is output per hour worked [or output per worker].)[7] In turn, productivity growth comes from innovations in technology and techniques of production.

Simply working more hours does not increase productivity. Indeed, Americans once routinely worked 50, 60, or even 70 hours per week. While some still do, the average workweek is shorter now (35 hours per week), and yet living standards are higher. Robert Solow got his Nobel Prize in economics for showing that increases in

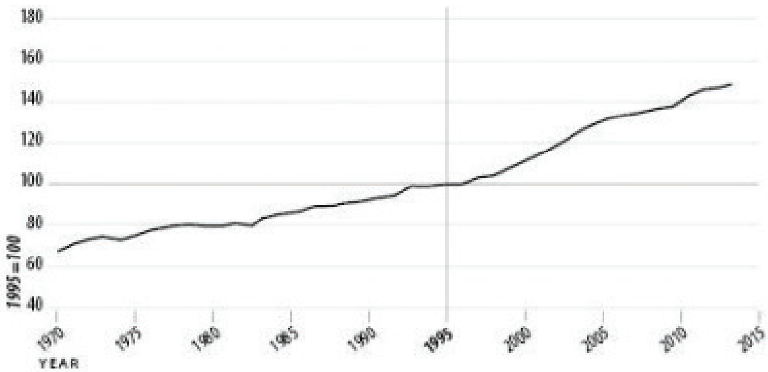
[4] The rule of 70 (or, more precisely, the rule of 69.3 percent) is based on the following equation: $(1 + x)y = 2$, where x is the rate of growth and y is the number of years. Taking the natural logarithm of both sides gives $y \ln(1 + x) = \ln 2$. The natural logarithm of 2 is 0.693 and for small x, $\ln(1 + x)$ is roughly equal to x, so the equation simplifies to $xy = 70$ percent.

[5] Swanson (2012).

[6] Congressional Budget Office (2013).

[7] One can also measure capital productivity, which is output per unit of capital input, or multifactor productivity, which is output divided by a weighted average of both capital and labor inputs. Economists sometimes use another term for multifactor productivity, the "Solow residual," which better reflects the fact that we don't necessarily know its origins. Robert Solow himself noted that it was less a concrete measure of technological progress than a "measure of our ignorance."

Figure 5.1
LABOR PRODUCTIVITY



labor input and capital input could not explain most of the increase in the total output of the economy.[8] In fact, it would take the average American only 11 hours of labor per week to produce as much as he or she produced in 40 hours in 1950. That rate of improvement is comparable for workers in Europe and Japan and even higher in some developing nations.[9]

Productivity improvement was particularly rapid in the middle part of the 20th century, especially the 1940s, 1950s, and 1960s, as the technologies of the first machine age, from electricity to the internal combustion engine, started firing on all cylinders. However, in 1973, productivity growth slowed down (see Figure 5.1).

[8] That's a good thing, because there are natural limits to how much we can increase inputs, especially labor. They're subject to diminishing returns—no one is going to work more than 24 hours a day, or employ more than 100 percent of the labor force. In contrast, productivity growth reflects ability to innovate—it's limited only by our imaginations.

[9] Output divided by labor and physical capital inputs is often more ambitiously called "total factor productivity." However, that term can be a bit misleading, because there are other inputs to production. For instance, companies can make major investments in intangible organizational capital. The more kinds of inputs we are able to measure, the better we can account for overall output growth. As a result, the residual that we label "productivity" (not explained by growth of inputs) will get smaller.

In 1987, Bob Solow himself noted that the slowdown seemed to coincide with the early days of the computer revolution, famously remarking, "We see the computer age everywhere, except in the productivity statistics."[10] In 1993, Erik published an article evaluating the "productivity paradox" that noted that computers were still a small share of the economy and that complementary innovations were typically needed before general-purpose technologies like information technology (IT) had their real impact.[11] Later work taking into account more detailed data on productivity and IT use among individual firms revealed a strong and significant correlation: the heaviest IT users were dramatically more productive than their competitors.[12] By the mid-1990s, these benefits were big enough to become visible in the overall U.S. economy, which experienced a general productivity surge. While this rise had a number of causes, economists now attribute the lion's share of those gains to the power of IT.[13]

The productivity slowdown in the 1970s and the subsequent speedup 20 years later had an interesting precedent. In the late 1890s, electricity was being introduced to American factories. But the "productivity paradox" of that era was that labor-productivity growth did not take off for over 20 years. While the technologies involved were very different, many of the underlying dynamics were quite similar.

University of Chicago economist Chad Syverson looked closely at the underlying productivity data and showed how eerily close this analogy is.[14] As shown in Figure 5.2, the slow start and subsequent acceleration of productivity growth in the electricity era matches well with the speedup that began in the 1990s. The key to understanding this pattern is the realization that general-purpose technologies (GPTs) always need complements. Coming up with those can take years, or even decades, and this creates lags between the introduction of a technology and the productivity benefits. We've clearly seen this with both electrification and computerization.

[10] Solow (1987).

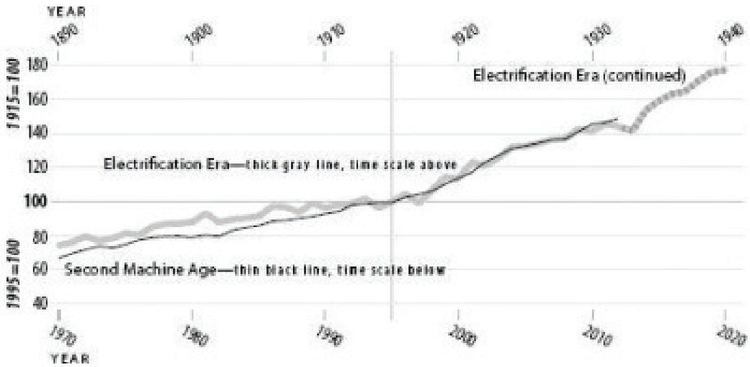
[11] Brynjolfsson (1993).

[12] See, for example, Brynjolfsson and Hitt (1996). See also Brynjolfsson and Hitt (2000), which summarizes much of the literature on this question.

[13] Jorgenson, Ho, and Stiroh (2004).

[14] Syverson (2013).

Figure 5.2
LABOR PRODUCTIVITY IN TWO ERAS



Perhaps the most important complementary innovations are the business-process changes and organizational co-inventions that new technologies make possible. Paul David, an economic historian at Stanford University and the University of Oxford, examined the records of American factories when they first electrified and found that they often retained a similar layout and organization to those that were powered by steam engines.[15] In a steam engine–driven plant, power was transmitted via a large central axle, which in turn drove a series of pulleys, gears, and smaller crankshafts. If the axle was too long, the torsion involved would break it, so machines needed to be clustered near the main power source, with those requiring the most power positioned closest. Exploiting all three dimensions, industrial engineers put equipment on floors above and below the central steam engines to minimize the distances involved.

Years later, when that hallowed GPT electricity replaced the steam engine, engineers simply bought the largest electric motors they could find and stuck them where the steam engines used to be. Even when brand-new factories were built, they followed the same design. Perhaps unsurprisingly, records show that the electric motors did not lead to much of an improvement in performance. There might have been less smoke and a little less noise, but the new technology was not always reliable. Overall, productivity barely budged.

[15] David (1989).

Only after 30 years—long enough for the original managers to retire and be replaced by a new generation—did factory layouts change. The new factories looked much like those we see today: a single story spread out over an acre or more. Instead of a single massive engine, each piece of equipment had its own small electric motor. Instead of putting the machines needing the most power closest to the power source, the layout was based on a simple and powerful new principle: the natural workflow of materials.

Productivity didn't merely inch upward on the resulting assembly lines; it doubled or even tripled. What's more, for most of the subsequent century, additional complementary innovations, from lean manufacturing and steel minimills to total quality management and six-sigma principles, continued to boost manufacturing productivity.

As with earlier GPTs, significant organizational innovation is required to capture the full benefit of second-machine-age technologies. Tim Berners-Lee's invention of the World Wide Web in 1989, to take an obvious example, initially benefited only a small group of particle physicists. But due in part to the power of digitization and networks to speed the diffusion of ideas, complementary innovations are happening faster than they did in the first machine age. Less than 10 years after its introduction, entrepreneurs were finding ways to use the Web to reinvent publishing and retailing.

While less visible, the large enterprise-wide IT systems that companies rolled out in the 1990s have had an even bigger impact on productivity.[16] They did this mainly by making possible a wave of business-process redesign. For example, Walmart drove remarkable efficiencies in retailing by introducing systems that shared point-of-sale data with their suppliers. The real key was the introduction of complementary process innovations such as vendor-managed inventory, cross-docking, and efficient consumer response that have become staple business-school case studies. They not only made it possible to increase sales from one billion dollars a week in 1993 to one billion dollars every 36 hours in 2001, but also helped drive dramatic increases in the entire retailing and distribution industries,

[16] For instance, materials resource planning systems, which begat enterprise resource planning, and then supply chain management, customer relationship management, and, more recently, business intelligence, analytics, and many other large-scale systems.

accounting for much of the additional productivity growth nationwide during this period.[17]

IT investment soared in the 1990s, peaking with a surge of investment in the latter half of the decade as many companies upgraded their systems to take advantage of the Internet, implement large enterprise systems, and avoid the much-hyped Y2K bug. At the same time, innovation in semiconductors took gigantic leaps, so the surging spending on IT delivered even more rapidly increasing levels of computer power. A decade after the computer-productivity paradox was popularized, Harvard's Dale Jorgenson, working with Kevin Stiroh at the New York Federal Reserve Bank, did a careful growth accounting and concluded, "A consensus has emerged that a large portion of the acceleration through 2000 can be traced to the sectors of the economy that produce information technology or use IT equipment and software most intensively."[18] But it's not just the computer-producing sectors that are doing well. Kevin Stiroh found that industries that were heavier users of IT tended to be more productive throughout the 1990s. This pattern was even more evident in recent years, according to a careful study by Harvard's Dale Jorgenson and two coauthors. They found that total factor productivity growth increased more between the 1990s and 2000s in IT-using industries, while it fell slightly in those sectors of the economy that did not use IT extensively.[19]

[17] Traub (2012).

[18] Jorgenson, Ho, and Stiroh (2004). This is consistent with a similar analysis by Oliner and Sichel (2002), who wrote, "both the use of information technology and the efficiency gains associated with the production of information technology were central factors in [the productivity] resurgence." Oliner, Sichel, and Stiroh (2007) also found that IT was a key factor in this resurgence. Susan Houseman, an economist at the Upjohn Institute, has argued that the enormous productivity gains of the computer-producing industries unfairly skew the productivity of the manufacturing sector (http://www.minneapolisfed.org/publications_papers/pub_display.cfm?id=4982). She says, "The computer industry is small—it only accounts for about 12 percent of manufacturing's value added. But it has an outsized effect on manufacturing statistics. . . . But we find that without the computer industry, growth in manufacturing real value added falls by two-thirds and productivity growth falls by almost half. It doesn't look like a strong sector without computers." However, we see the glass as half full and welcome the contribution of computers even as other sectors lag.

[19] See Stiroh (2002) and Jorgenson, Ho, and Samuels (2011), especially Table 5, which shows the total factor productivity growth was about 10 times higher in IT-using sectors than in sectors that did not use IT extensively.

It's important to note that the correlation between computers and productivity is not just evident at the industry level; it occurs at the level of individual firms as well. In work Erik did with Lorin Hitt of the University of Pennsylvania's Wharton School, he found that firms that use more IT tend to have higher levels of productivity and faster productivity growth than their industry competitors.[20]

The first five years of the 21st century saw a renewed wave of innovation and investment, this time less focused on computer hardware and more focused on a diversified set of applications and process innovations. For instance, as Andy described in a case study he did for Harvard Business School, CVS found that their prescription-drug-ordering process was a source of customer frustration; so they redesigned and simplified it.[21] By embedding the steps in an enterprise-wide software system, they were able to replicate the drug-ordering process in over 4,000 locations, dramatically boosting customer satisfaction and ultimately profits. CVS was not atypical. In a statistical analysis of over 600 firms that Erik did with Lorin Hitt, he found it takes an average of five to seven years before the full productivity benefits of computers are visible in the productivity of the firms making the investments. This reflects the time and effort required to make the other, complementary investments that bring a computerization effort success. In fact, for every dollar of investment in computer hardware, companies need to invest up to another nine dollars in software, training, and business-process redesign.[22]

The effects of organizational changes such as these became increasingly visible in the industry-level productivity statistics.[23] The productivity surge in the 1990s was most visible in computer-producing industries, but overall productivity grew even faster in the early years of the 21st century, when a much broader set of industries saw significant productivity gains. Like earlier GPTs, the power of computers was their ability to affect productivity far from their "home" industry.

[20] See Brynjolfsson and Hitt (2003). Similarly, Stanford University's Nicholas Bloom, Harvard University's Raffaella Sadun, and the London School of Economics's John Van Reenen found that American firms were particularly adept at implementing management practices that maximized the value of IT, and this led to measurable productivity improvements, as documented. See Bloom, Sadun, and Van Reenen (2007).

[21] McAfee (2005).

[22] Brynjolfsson, Hitt, and Yang (2002).

[23] More details can be found in Brynjolfsson and Saunders (2013).

Overall, American productivity growth in the decade following the year 2000 exceeded even the high growth rates of the roaring 1990s, which in turn were higher than 1970s or 1980s growth rates had been.[24]

Today, American workers are more productive than they've ever been, but a closer look at recent numbers tells a more nuanced story. The good performance since the year 2000 was clustered in the early years of the decade. Since 2005, productivity growth has not been as strong. This has led to a new wave of worries about the "end of growth" by economists, journalists, and bloggers. We are not convinced by the pessimists. The productivity lull after the introduction of electricity did not mean the end of growth, nor did the lull in the 1970s.

Part of the recent slowdown simply reflects the Great Recession and its aftermath. Recessions are always times of pessimism, which is understandable, and the pessimism invariably spills over into predictions about technology and the future. The financial crisis and burst of the housing bubble led to a collapse of consumer confidence and wealth, which translated into dramatically lower demand and GDP. While the recession technically ended in June 2009, as we write this in 2013 the U.S. economy is still operating well below its potential, with unemployment at 7.6 percent and capacity utilization at 78 percent. During such a slump, any metric that includes output in the numerator, such as labor productivity, will often be at least temporarily depressed. In fact, when you look at history, you see that in the early years of the Great Depression, in the 1930s, productivity didn't just slow but actually fell for two years in a row—something it never did in the recent slump. Growth pessimists had even more company in the 1930s than they do today, but the following three decades proved to be the best ones of the 20th century. Go back to Figure 5.2 and look most closely at the dashed line charting the years following the dip in productivity in the early 1930s. You'll see the biggest wave of growth and bounty that the first machine age ever delivered.

The explanation for this productivity surge is in the lags that we always see when GPTs are installed. The benefits of electrification stretched for nearly a century as more and more complementary innovations were implemented. The digital GPTs of the second machine

[24] According to the U.S. Bureau of Labor Statistics, productivity growth averaged 2.4 percent between 2001 and 2010, 2.3 percent between 1991 and 2000, 1.5 percent between 1981 and 1990, and 1.7 percent between 1971 and 1980.

age are no less profound. Even if Moore's law ground to a halt today, we could expect decades of complementary innovations to unfold and continue to boost productivity. However, unlike the steam engine or electricity, second-machine-age technologies continue to improve at a remarkably rapid exponential pace, replicating their power with digital perfection and creating even more opportunities for combinatorial innovation. The path won't be smooth—for one thing, we haven't banished the business cycle—but the fundamentals are in place for bounty that vastly exceeds anything we've ever seen before.

Beyond GDP

> *"The Gross National Product does not include the beauty of our poetry or the intelligence of our public debate. It measures neither our wit nor our courage, neither our wisdom nor our learning, neither our compassion nor our devotion. It measures everything, in short, except that which makes life worthwhile."*
>
> *—Robert F. Kennedy*

When President Hoover was trying to understand what was happening during the Great Depression and design a program to fight it, a comprehensive system of national accounts did not exist. He had to rely on scattered data, such as freight-car loadings, commodity prices, and stock-price indexes, that gave only an incomplete and often unreliable view of economic activity. The first set of national accounts was presented to Congress in 1937 based on the pioneering work of Nobel Prize winner Simon Kuznets, who worked with researchers at the National Bureau of Economic Research and a team at the U.S. Department of Commerce. The resulting metrics have served as beacons that helped illuminate many of the dramatic changes that transformed the economy throughout the 20th century.

But as the economy has changed, so too must our metrics. More and more, what we care about in the second machine age are ideas, not things: mind, not matter; bits, not atoms; and interactions, not transactions. The great irony of this information age is that, in many ways, we actually know less about the sources of value in the economy than we did 50 years ago. In fact, much of the change has been invisible for a long time simply because we did not know what to look for. There's a huge layer of the economy unseen in the official data and, for that matter, unaccounted for on the income statements and balance sheets of most companies. Free digital goods, the sharing economy, intangibles, and changes in our relationships have already had big effects on our well-being. They also call for new organizational structures, new skills, new institutions, and perhaps even a reassessment of some of our values.

Music to Your Ears

The story of music's move from physical media to computer files has been told often and well, but one of that transition's most interesting aspects is less discussed. Music is hiding itself from our traditional economic statistics. Sales of music on physical media declined from 800 million units in 2004 to less than 400 million units in 2008. Yet, over the same time period, total units of music purchased still grew, reflecting an even-faster increase in the purchases of digital downloads. Digital streams such as iTunes, Spotify, or Pandora also came to prominence, and, of course, the purchase data don't reflect the even-larger number of songs that were shared, streamed, or downloaded for free, often via piracy. Before the rise of the MP3, even the most fanatical music fan, with a basement stacked high with LPs, tapes, and CDs, wouldn't have had a fraction of the 20 million songs available on a child's smartphone via services like Spotify or Rhapsody. What's more, clever research by Joel Waldfogel at the University of Minnesota finds quantitative evidence that the overall quality of music has not declined over the past decade and is, if anything, higher than ever.[25] If you're like most people, you are listening to more and better music than ever before.

So how did music disappear? The value of music has not changed, only the price. From 2004 to 2008, the combined revenue from sales of music dropped from \$12.3 billion to \$7.4 billion—that's a decline of 40 percent. Even when we include all digital sales, throwing in ringtones on mobile phones for good measure, the total revenues to the record companies are still down 30 percent.

Similar economics apply when you read the *New York Times*, *Bloomberg Businessweek*, or *MIT Sloan Management Review* online at a reduced price or for free instead of buying a physical copy at the newsstand, or when you use Craigslist instead of the classified ads, or

[25] Waldfogel (2011).

when you share photos via Facebook instead of mailing prints around to friends and relatives. Analog dollars are becoming digital pennies.

By now, the number of pages of digital text and images on the Web is estimated to exceed one trillion.[26] Bits are created at virtually zero cost and transmitted almost instantaneously worldwide. What's more, a copy of a digital good is exactly identical to the original. This leads to some very different economics and some special measurement problems. When business travelers call home to talk to their children via Skype, that may add zero to GDP, but it's hardly worthless. Even the wealthiest robber baron would have been unable to buy this service. How do we measure the benefits of free goods or services that were unavailable at any price in previous eras?

What GDP Leaves Out

Despite all the attention it gets from economists, pundits, journalists, and politicians, GDP, even if it were perfectly measured, does not quantify our welfare. The trends in GDP growth and productivity growth are important, but they are not sufficient measures of our overall well-being or even our economic well-being. Robert Kennedy put this poetically in his quote provided above.

While it would be unrealistic to put a dollar value on stirring oratory like RFK's, we can do a better job of understanding our basic economic progress by considering some of the changes in the goods and services that we are able to consume. It soon becomes clear that the trends in the official statistics not only underestimate our bounty, but in the second machine age have also become increasingly misleading.

In addition to their vast library of music, children with smartphones today have access to more information in real time via the mobile smartphone than the president of the United States had 20 years ago. Wikipedia alone claims to have over 50 times as much information as *Encyclopaedia Britannica*, the premier compilation of knowledge for most of the 20th century.[27] Like Wikipedia but unlike *Britannica*, much of the information and entertainment available today is free, as are over one million apps on smartphones.[28]

[26] Gore (2013, p. 45).

[27] The English Wikipedia has over 2.5 billion words, which is over 50 times as many as *Encyclopaedia Britannica*. See Wikipedia (2013).

[28] Actually, 90 percent of apps on smartphones are now free. See Cocotas (2013).

Because they have a zero price, these services are virtually invisible in the official statistics. They add value to the economy, but not dollars to GDP. And because our productivity data are, in turn, based on GDP metrics, the burgeoning availability of free goods does not move the productivity dial. There's little doubt, however, that they have real value. When a girl clicks on a YouTube video instead of going to the movies, she's saying that she gets more net value from YouTube than traditional cinema. When her brother downloads a free gaming app on his iPad instead of buying a new video game, he's making a similar statement.

Free: Good for Well-Being, Bad for GDP

In some ways, the proliferation of free products even pushes GDP downward. If the cost of creating and delivering an encyclopedia to your desktop is a few pennies instead of thousands of dollars, then you're certainly better off. But this decrease in costs lowers GDP even as our personal well-being increases, leaving GDP to travel in the opposite direction of our true well-being. A simple switch to using a free texting service such as Apple's iChat instead of SMS (short message service), free classifieds such as Craigslist instead of newspaper ads, or free calls such as Skype instead of a traditional telephone service can make billions of dollars disappear from companies' revenues and the GDP statistics.[29]

As these examples show, our economic welfare is only loosely related to GDP. Unfortunately, many economists and journalists and much of the general public still use "GDP growth" as a synonym for "economic growth." For much of the 20th century, this was a fair comparison. If one assumes that each additional unit of production created a similar increment in well-being, then counting up how many units were produced, as GDP does, would be a fine approximation of welfare. A

[29] Cannibalization of short message services by free over-the-top services is estimated to have cost telephone companies over $30 billion in 2013, according to the analyst group Ovum. See Philipson (2013). In theory, the hardworking statisticians at the Bureau of Economic Analysis try to account for quality-adjusted price changes. In practice, this works for small changes but not for highly disruptive introductions of new products and services. What's more, sometimes increases in GDP reflect declines in our well-being. For instance, an increase in crime might prompt more spending on burglar alarms, police services, and prisons. Every dollar spent on these activities increases GDP, but of course the nation would be better off with less crime and less need for this kind of spending.

nation that sells more cars, more bushels of wheat, and more tons of steel probably corresponds to a nation whose people are better off.

With a greater volume of digital goods introduced each year that do not have a dollar price, this traditional GDP heuristic is becoming less useful. The second machine age is often described as an "information economy," and with good reason. More people than ever are using Wikipedia, Facebook, Craigslist, Pandora, Hulu, and Google, with thousands of new digital goods introduced each year.

The U.S. Bureau of Economic Analysis defines the information sector's contribution to the economy as the sum of the sales of software, publishing, motion pictures, sound recording, broadcasting, telecommunications, and information- and data-processing services. According to the official measures, these account for just 4 percent of our GDP today, almost precisely the same share of GDP as in the late 1980s, before the World Wide Web was even invented. But clearly this isn't right. The official statistics are missing a growing share of the real value created in our economy.

Measuring Growth with a Time Machine: Would You Rather . . . ?

Can we improve on GDP as a measure of well-being? Economists sometimes use an alternate approach that resembles the children's game "Would you rather . . . ?" The 1912 Sears shopping catalog had thousands of items for sale, from a "Sears Motor Car" for $335 (p. 1213) to dozens of pairs of women's shoes, some available for as little as $1.50 (pp. 371–79). Suppose I gave you an expanded version of this catalog that listed all the goods and services available in 1912, not just from Sears but from any seller in the economy of 1912, and all the same prices as 1912.[30] Would you rather shop exclusively in that old catalog, with no other choices, or would you rather pay today's prices for a full selection of today's goods and services?

Or to make the comparison less difficult, pick two more recent catalogs, such as 1993 versus 2013. If you had $50,000 to spend, would you rather be able to buy any 1993-model car (it would be brand new) and pay 1993 prices, or a 2013 car and pay 2013 prices? Would you rather be able to buy the bananas, contact lenses, chicken wings, shirts, chairs, banking services, airline tickets, movies, telephone service, health care,

[30] See http://archive.org/stream/catalogno12400sear#page/370/mode/2up (accessed September 15, 2013).

housing services, light bulbs, computers, gasoline, and other goods and services that were available in 1993 at 1993 prices? Or would you rather buy the equivalent 2013 basket of services at 2013 prices?

Bananas or a gallon of gasoline have not really changed qualitatively since 1993, so the only difference to consider is their price. If that were the only difference, inflation would be easy to calculate, and the "would you rather" comparison would be a lot easier too. For other goods, though, especially second-machine-age goods such as online information and mobile-phone capabilities, there have been big changes in quality, so the real quality-adjusted price may have fallen even if the nominal sticker price has increased. What's more, there are a lot of new goods that didn't exist before, especially digital goods. There are also some older goods and services that have been discontinued or degraded. It's hard to find a good horsehide razor strop these days,[31] or a 1993 vintage personal computer, or a gas station where the attendants routinely wash your windshield for no charge, like they once did.

Once you pick which catalog you like better, the next step asks how much money I would have to pay you to make you indifferent between the two catalogs. If I have to pay you 20 percent more to make you just as happy shopping from the new catalog as you would be shopping from the old catalog, then the overall price index has increased by 20 percent. And if your income has not changed, then that erosion of purchasing power translates to an equivalent fall in your standard of living. Similarly, if your income increases faster than the price index, then your standard of living is increasing.

This approach makes sense conceptually, and it's the basis for the way most modern governments calculate changes in the standard of living. For instance, the cost-of-living adjustments used to index Social Security payments are based on this kind of analysis.[32]

[31] Try the 1912 Sears catalog (p. 873), where it's priced at just 72 cents; see http://archive.org/stream/catalogno12400sear#page/872/mode/2up.

[32] It turns out that you get a slightly different answer depending on whether you try to replicate the "happiness" that you had in 1993 using the 2013 catalog or replicate the happiness of the 2013 catalog using the 1993 catalog. Technically this is the difference between what economists call the Paasche and Laspeyres Price Indexes. An alternative is to continually adjust the basket of goods being considered, which is the approach used in so-called chained price indexes. The choice of price index, while subtle, can lead to hundreds of billions of dollars in differences over time, as in the case of indexing Social Security payments for changes in the cost of living.

But the data used for these calculations are almost always drawn, understandably, from market transactions where money changes hands. The free economy is not factored in.

Consumer Surplus: How Much Would You Pay If You Had To?

An alternative approach measures the consumer surplus generated by goods and services. Consumer surplus compares the amount a consumer would have been willing to pay for something to the amount they actually have to pay. If you would happily pay one dollar to read the morning newspaper, but instead you get it for free, then you've just gained one dollar of consumer surplus. However, as noted above, replacing a paid newspaper with an equivalent free new service would decrease GDP even though it increased consumer surplus.[33] In this case, consumer surplus would be a better measure of our economic well-being. Yet, as appealing as consumer surplus is as a concept, it is also extremely difficult to measure.

The difficulty in measuring the consumer surplus, however, has not stopped a number of researchers from trying to eke out some estimates. In 1993, Erik wrote a paper calculating that the rapidly growing consumer surplus from price declines in computers increased economic welfare by about $50 billion each year.[34]

Of course, when the product being studied is already free, looking at price declines doesn't work. Recent research that Erik did with Joo

[33] In principle, when the exact same good is available for a lower price, the nominal GDP would fall, but the real GDP would not, with the difference being reflected in the price index. In practice, such changes in consumption as this are not picked up in changes in price indexes, and thus official numbers for both nominal and real GDP fall.

[34] Brynjolfsson (1996). There have been a number of related findings since then. Recently, economists Jeremy Greenwood and Karen Kopecky applied a similar approach and found a similar growth contribution for personal computers alone. Shane Greenstein and Ryan McDevitt, another pair of economists, asked how much consumer surplus was created by the spread of broadband Internet access. They looked at how the real price of broadband had declined over time and how adoption of the service had increased. From that, they estimate how much people would have been willing to pay compared to what they actually paid, and thus arrive at the consumer surplus. A research team at McKinsey took a more direct approach. The team asked 3,360 consumers what they would have been willing to pay for 16 specific services available via the Internet. The average willingness to pay added up to $50 per month. Based on this, the team estimated that Americans received over $35 billion worth of consumer surplus from the free Internet. The biggest single category was email, with such social networks as Facebook close behind.

Hee Oh, a postdoctoral student at MIT, took a different approach. They started with the observation that even when people don't pay with money, they still give up something valuable whenever they use the Internet: their time.[35] No matter how rich or poor we are, each of us gets 24 hours in a day. In order to consume YouTube, Facebook, or email, we must "pay" attention. In fact, Americans nearly doubled the amount of leisure time they spent on the Internet between 2000 and 2011. This implies that they valued it more than the other ways they could spend their time. By considering the value of users' time and comparing leisure time spent on the Internet to time spent in other ways, Erik and Joo Hee estimated that the Internet created about $2,600 of value per user each year. None of this showed up in the GDP statistics, but if it had, GDP growth—and thus productivity growth—would have been about 0.3 percent higher each year. In other words, instead of the reported 1.2 percent productivity growth for 2012, it would have been 1.5 percent.

In contrast to leisure, where more time is a good thing, value at work is created by saving time. Hal Varian, the chief economist at Google, looked specifically at time savings gained from Google searches.[36] He and his team gathered a random sample of Google queries, such as "In making cookies, does the use of butter or margarine affect the size of the cookie?" The team then did their best job to answer the questions without using Google—by looking answers up in the library, for instance. On average it took about 22 minutes to answer a query without Google (not counting travel time to the library!) but only 7 minutes to answer the same query with Google. Google saved an average of 15 minutes per query. When you multiply that time difference out across all the queries that the average American makes using the average hourly wage of Americans ($22), that works out to about $500 per adult worker per year.

As anyone who has been caught up in the pleasures of surfing the Web (perhaps while "doing research" for a book) can attest, though, the strict distinction between work and play or input and output that economists make is not always so clear. The billions of hours that people spend uploading, tagging, and commenting on photos on social-media sites such as Facebook unquestionably create value

[35] Brynjolfsson and Oh (2012).

[36] Varian (2011); Chen, Jeon, and Kim (2010).

for their friends, family, and even strangers. Yet at the same time, these hours are uncompensated, so presumably the people doing this "work" find it more intrinsically rewarding than the next-best use of their time. To get a sense of the scale of this effort, consider that last year users collectively spent about 200 million hours each day just on Facebook, much of it creating content for other users to consume.[37] That's 10 times as many person-hours as were needed to build the entire Panama Canal.[38] None of this is counted in our GDP statistics as either input or output, but these kinds of zero-wage and zero-price activities still contribute to welfare. Researchers such as Luis von Ahn at Carnegie Mellon are working on ways of motivating and organizing millions of people to create value via collective projects on the Internet.[39]

New Goods and Services

In the early days of the 1990s' Internet boom, venture capitalists used to joke that there were only two numbers in the new economy: infinity and zero. Certainly, a big part of the value in the new economy has come from the reduction in the price of many goods to zero. But what about the other end of that spectrum, price drops from infinity down to some finite number? Suppose Warner Bros. makes a new movie and you can watch it for nine dollars. Has your welfare increased? Before the movie was conceived, cast, filmed, and distributed, you couldn't buy it at any price, even infinity. In a sense, paying just nine bucks is a pretty large price reduction from infinity, or whatever the maximum price was that you would have been willing to pay. Similarly, we now have access to all sorts of new services that never existed before. Much of the increase in our welfare over the past century comes not just from making existing goods more cheaply but from expanding the range of goods and services available.

Seventy-seven percent of software companies report the introduction of new products each year, and Internet retailing has vastly expanded the set of goods available to most consumers.[40] With a few

[37] Protalinski (2012).

[38] Weld (2013).

[39] For a good overview, see Thompson (2007).

[40] National Science Foundation (2012).

clicks, over two million books can be found and purchased at Amazon.com. By contrast, the typical physical bookstore has about 40,000 titles, and even the largest Barnes & Noble store in New York City stocks only 250,000 titles. As documented in a research paper that Erik Brynjolfsson wrote with Michael Smith and Jeffrey Hu (2006), there have been similar increases in the online selection for other categories such as videos, music, electronics, and collectibles. Every time a new product is made available, it increases consumer surplus.

One way to think of the value created is to imagine that the new product always existed, but only at such a high price that no one could buy it. Making it available is like lowering the price to a more reasonable level. There have even been substantial increases in the number of stock-keeping units (SKUs) in most physical stores as computerized inventory-management systems, supply chains, and manufacturing have become more efficient and flexible. For the overall economy, the official GDP numbers miss the value of new goods and services added to the tune of about 0.4 percent of additional growth each year, according to economist Robert Gordon. Remember that productivity growth has been in the neighborhood of 2 percent per year for most of the past century, so contribution of new goods is not a trivial portion.

Reputations and Recommendations

Digitization also brings a related but subtler benefit to the vast array of goods and services that already exist in the economy. Lower search and transaction costs mean faster and easier access and increased efficiency and convenience. For example, the rating site Yelp collects millions of customer reviews to help diners find nearby restaurants in the quality and price ranges they seek, even when they are visiting new cities. The reservation service OpenTable then lets them book a table with just a few mouse clicks.

In aggregate, digital tools such as these make a large difference. In the past, ignorance protected inefficient or lower-quality sellers from being unmasked by suspecting consumers, while geography limited competition from other sellers. With the introduction of structured comparison sites such as FindTheBest.com and Kayak, airline travel, banking, insurance, car sales, motion pictures, and many other industries are being transformed by consumers' ability to search for and compare competing sellers. No longer can a seller of substandard services expect to feed on a continuing stream of naïve or ill-informed consumers. No longer can the seller expect to be insulated from competitors in other locations who can deliver a better service for less. Research by Michael Luca of Harvard Business School has found that the increased transparency has helped smaller independent restaurants compete with bigger chains because customers can more quickly find quality food via rating services such as Yelp, reducing their reliance on brand names' expensive marketing campaigns.[41]

The intangible benefits delivered by the growing sharing economy—better matches, timeliness, customer service, and convenience—are exactly the types of benefits identified by the 1996 Boskin Commission as being poorly measured in our official price and GDP statistics.[42] This is another way in which our true growth is greater than the standard data suggest.

Intangible Assets

Just as free goods rather than physical products are an increasingly important share of consumption, intangibles also make up a growing share of the economy's capital assets. Production in the second machine age depends less on physical equipment and structures and more on the four categories of intangible assets: intellectual property, organizational capital, user-generated content, and human capital.

Intellectual property includes patents and copyrights. The rate of patenting by American inventors has been increasing rapidly since the 1980s,[43] and other types of intellectual assets have also grown.[44] In addition, a lot of research and development is never formalized as intellectual property but is still very valuable.

The second—and even larger—category of intangibles is organizational capital such as new business processes, techniques of production, organizational forms, and business models. Effective uses of the new technologies of the second machine age almost invariably require changes in the organization of work. For instance, when companies spend millions of dollars on computer hardware and software for a new enterprise resource planning system, they

[41] Luca (2011).

[42] Turvey (1997).

[43] Rothwell et al. (2013).

[44] See Corrado, Hulten, and Sichel (2006).

typically also include process changes that are three to five times as costly as the original investments in hardware and software. Yet, while the hardware and software spending generally shows up as additions to the nation's capital stock, the new business processes, which often outlast the hardware, are generally not counted as capital. Our research suggests that a correct accounting for computer-related intangible assets would add over two trillion dollars to the official estimates of the capital assets in the U.S. economy.[45]

User-generated content is a smaller but rapidly growing third category of intangible assets. Users of Facebook, YouTube, Twitter, Instagram, Pinterest, and other types of online content not only consume this free content and gain the consumer surplus discussed above but also produce most of the content. There are 43,200 hours of new YouTube videos created each day,[46] as well as 250 million new photos uploaded each day on Facebook.[47] Users also contribute valuable but unmeasured content in the form of reviews on sites such as Amazon, TripAdvisor, and Yelp. In addition, user-generated content includes the simple binary information used to sort reviews and present the best content first (e.g., when Amazon asks, "Was this review helpful to you?"). Hardware and software companies now compete to improve the productivity of user-generated-content activities. For example, smartphones and apps for smartphones now include easy or automatic tools for posting photos on Facebook. This content has value to other users and can be thought of as yet-another type of intangible capital asset that is being added to our collective wealth.

The fourth and biggest category is the value of human capital. The many years that we all spend in schools learning skills such as reading, writing, and arithmetic—as well as the additional learning that happens on the job and on our own—makes us more productive and, in some cases, is intrinsically rewarding. It is also a contribution to the nation's capital stock. According to Dale Jorgenson and Barbara Fraumeni, the value of human capital in the United States is 5 to 10 times larger than the value of all the physical capital in the

[45] Brynjolfsson, Hitt, and Yang (2002); Brynjolfsson and Hitt (2003).

[46] Burgess (2013).

[47] "Facebook Newsroom," http://newsroom.fb.com/content/default.aspx?NewsAreaId=21 (accessed July 23, 2013).

United States.[48] Human capital has not always been this important to the economy. The great economist Adam Smith understood that one of the great drawbacks of the first machine age was the way it forced workers to do repetitive tasks. In 1776, he noted, "The man whose whole life is spent in performing a few simple operations, of which the effects are perhaps always the same, or very nearly the same, has no occasion to exert his understanding."[49] In the future, however, investments in human capital will be increasingly important as routine tasks become automated and the need for human creativity increases.

Important as these intangible assets are, the official GDP statistic ignores them. User-generated content, for example, involves unmeasured labor creating an unmeasured asset that is consumed in unmeasured ways to create unmeasured consumer surplus. In recent years, however, there have been some efforts to create experimental "satellite accounts." They track some of these categories of intangible assets in the U.S. economy. For instance, the new satellite accounts created by the Bureau of Economic Analysis estimate that investment in research and development capital accounted for about 2.9 percent of GDP and has increased economic growth by about 0.2 percent per year between 1995 and 2004.[50]

It's hard to say exactly how large the bias is from miscounting all the types of intangible assets, but we are reasonably confident the official data underestimate their contribution.[51]

[48] Jorgenson and Fraumeni (1989, p. 230).

[49] Smith (1904).

[50] Aizcorbe, Moylan, and Robbins (2009).

[51] Unlike unmeasured intangible consumption goods, the bad measures of intangible capital goods don't automatically bias official productivity statistics. On one hand, like all intangibles, intangible capital goods make the output numbers bigger. But at the same time, they are also used for production and thus make the input numbers bigger. In a steady state where both the input and output numbers are growing at the same rate, these two effects cancel out, so there is no bias in the productivity numbers, defined as output/input. Steady growth has been roughly true for some types of intangibles, such as the human-capital assets that are created by education. But other categories—such as computer-related organizational capital or the user-generated capital on digital-content sites—appears to have been growing rapidly. For these categories of intangible assets, the official productivity numbers understate the true growth of the economy.

New Metrics Are Needed for the Second Machine Age

It's a fundamental principle of management: what gets measured gets done. Modern GDP accounting was certainly a huge step forward for economic progress. As Paul Samuelson and Bill Nordhaus put it, "While the GDP and the rest of the national income accounts may seem to be arcane concepts, they are truly among the great inventions of the twentieth century."[52]

But the rise in digital business innovation means we need innovation in our economic metrics. If we are looking at the wrong gauges, we will make the wrong decisions and get the wrong outputs. If we measure only tangibles, then we won't catch the intangibles that will make us better off. If we don't measure pollution and innovation, then we will get too much pollution and not enough innovation. Not everything that counts can be counted, and not everything that can be counted counts.

As Nobel Prize winner Joe Stiglitz put it,

> the fact that GDP may be a poor measure of well-being, or even of market activity, has, of course, long been recognized. But changes in society and the economy may have heightened the problems, at the same time that advances in economics and statistical techniques may have provided opportunities to improve our metrics.[53]

The new metrics will differ both in conception and execution. We can build on some of the existing surveys and techniques researchers have been using. For instance, the human development index uses health and education statistics to fill in some of the gaps in official GDP statistics;[54] the multidimensional poverty index uses 10 different indicators—such as nutrition, sanitation, and access to water—to assess well-being in developing countries.[55] Childhood death rates and other health indicators are recorded in periodic household surveys such as the Demographic and Health Surveys.[56]

[52] As quoted in Landefeld (2000, p. 6).

[53] Stiglitz (2009, p. 1).

[54] United Nations Development Programme (2012).

[55] Oxford Poverty & Human Development Initiative (2013).

[56] DHS Program (2013).

There are several promising projects in this area. Joe Stiglitz, Amartya Sen, and Jean-Paul Fitoussi have created a detailed guide for how we can do a comprehensive overhaul of our economic statistics.[57] Another promising project is the Social Progress Index that Michael Porter, Scott Stern, Roberto Loria, and their colleagues are developing.[58] In Bhutan, they've begun measuring "Gross National Happiness." There is also a long-running poll behind the Gallup-Healthways Well-Being Index.[59]

These are all important improvements, and we heartily support them. But the biggest opportunity is in using the tools of the second machine age itself: the extraordinary volume, variety, and timeliness of data available digitally. The Internet, mobile phones, embedded sensors in equipment, and a plethora of other sources are delivering data continuously. For instance, Roberto Rigobon and Alberto Cavallo measure online prices from around the world on a daily basis to create an inflation index that is far timelier and, in many cases, more reliable than official data gathered via monthly surveys with much smaller samples.[60] Other economists are using satellite mapping of nighttime artificial light sources to estimate economic growth in different parts of the world and assessing the frequency of Google searches to understand changes in unemployment and housing.[61] Harnessing this information will produce a quantum leap in our understanding of the economy, just as it has already changed marketing, manufacturing, finance, retailing, and virtually every other aspect of business decisionmaking.

As more data become available and as the economy continues to change, the ability to ask the right questions will become even more vital. No matter how bright the light is, you won't find your keys by searching under a lamppost if that's not where you lost them. We must think hard about what it is we really value, what we want more of, and what we want less of. GDP and productivity growth are important, but they are means to an end, not ends in and of themselves. Do we want to increase consumer surplus? Then lower prices or more

[57] Stiglitz, Sen, and Fitoussi (2010).

[58] See the Social Progress Index at http://www.socialprogressimperative.org/data/spi.

[59] See the Well-Being Index at http://www.well-beingindex.com/.

[60] See the MIT Billion Prices Project at http://bpp.mit.edu.

[61] See, for example, Choi and Varian (2009); Wu and Brynjolfsson (2013).

leisure might be signs of progress, even if they result in a lower GDP. And of course, many of our goals are nonmonetary. We shouldn't ignore the economic metrics, but neither should we let them crowd out our other values simply because they are more measurable.

In the meantime, we need to bear in mind that the GDP and productivity statistics overlook much of what we value, even when using a narrow economic lens. What's more, the gap between what we measure and what we value grows every time we gain access to a new good or service that never existed before or when existing goods become free, as they so often do when they are digitized.

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6. Information Technology and Productivity Growth

Stephen D. Oliner[1]

Introduction

The rate of increase in labor productivity in the United States slowed sharply around 2004, after having surged for roughly a decade. A substantial body of research (see, for example, Oliner, Sichel, and Stiroh 2007) has concluded that the productivity boom from the mid-1990s to 2004 reflected a huge step-up in the growth contribution from information technology (IT).

Important questions remain, however, concerning both the more recent history and the outlook for IT and productivity growth. Is the return to slower productivity gains after 2004 linked to IT? Has innovation in the semiconductor sector—the engine that powers the development and diffusion of advances in IT—begun to stall out? And, finally, what are the prospects for a return to faster productivity growth? Views about the future range from the pessimism expressed by Robert Gordon (see Gordon, 2012, 2014a, and 2014b) to the much brighter outlook envisioned by Erik Brynjolfsson and Andrew McAfee (2014).

This paper addresses all three questions, drawing heavily on research with David Byrne and Daniel Sichel.[2] Our research shows that the return to slower productivity gains roughly a decade ago was indeed linked to IT, which has been providing much less impetus to growth than in the prior decade. At the same time, semiconductor technology has continued to advance, and chip prices have

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[2] See Byrne, Oliner, and Sichel (2013, 2015).

continued to drop at a rapid pace, contrary to the picture painted by the official price data. Thus, the underlying force that would be needed to power a second IT-centric productivity wave remains intact. That said, the outlook for productivity growth over the coming decade is cloudy. Economists have a terrible track record when it comes to forecasting productivity growth, and confident predictions should be regarded with considerable skepticism.

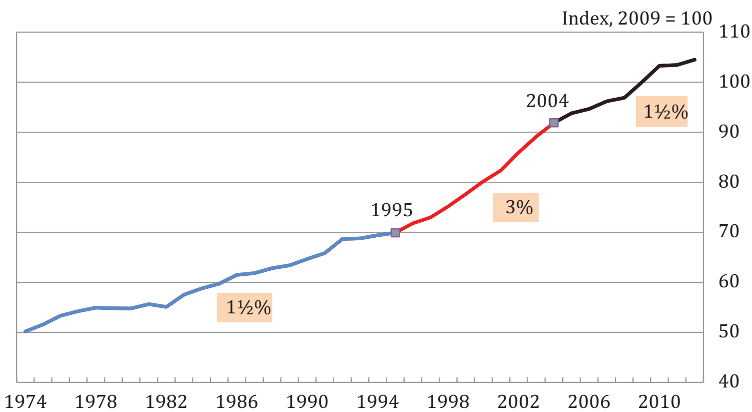
Productivity Growth and Information Technology: A Look Backward

Reasonably consistent data on output per hour worked in the United States go back to 1889. Since then, output per hour has increased about 2.25 percent per year on average. Compounded over a period of 125 years, this average annual rise cumulates to roughly a 15-fold increase in labor productivity, generating a huge improvement in living standards.

Viewed against this long historical record, the recent performance of productivity has been lackluster. Figure 6.1 plots the data for output per hour worked in the nonfarm-business sector from 1974 to 2012, broken into three periods: 1974–95, 1995–2004, and 2004–12.

Figure 6.1

REAL OUTPUT PER HOUR IN THE NONFARM-BUSINESS SECTOR



SOURCE: Bureau of Labor Statistics.

During the first period, output per hour grew at an average annual rate of about 1.5 percent, well below the long-term average pace of 2.25 percent. Productivity growth strengthened from 1995 to 2004, rising about 3 percent per year. But since 2004, the trend increase in output per hour has returned to the slow pace recorded from 1974 to 1995. Notably, this slowdown predated the onset of the financial crisis. Thus, while the dislocations produced by the crisis may have damped the gains in productivity, they are not the root cause of the slowdown.[3]

To analyze the growth in output per hour, economists distinguish between the contributions from two main sources: capital deepening and multifactor productivity (MFP). Capital deepening contributes to growth in output per hour by increasing the amount of equipment and other types of capital used by workers, while MFP refers to the ability to produce more output with a given amount of capital and labor. For example, if I become more productive by replacing my old computer with a new, more powerful one, that increase in output per hour is the result of capital deepening. But even with my old computer, the Internet made it possible to find information many times faster than before the Web existed, which represents an increase in MFP.

In addition to capital deepening and MFP growth, a third source of growth in output per hour is the change in the composition of the workforce. A well-educated employee with many years of job experience likely will produce more in an hour than a less-educated employee who just finished school. Consequently, output per hour will grow more rapidly, all else equal, when highly productive employees account for a disproportionate share of the rise in hours worked, and vice versa.

Byrne, Oliner, and Sichel (2013) implemented a growth decomposition of this type for the period 1974–2012, using data from the Bureau of Labor Statistics, the National Income and Product Accounts, and other sources. The details regarding the methodology and data can be found in that article and in a separate data appendix (posted at http://www.csls.ca/ipm/25/appendix-byrne-oliner-sichel.pdf).

Table 6.1 presents the main results. The table shows the growth contributions from all three factors—capital deepening, MFP, and changes

[3] See Fernald (2015) for additional evidence that supports this conclusion.

Table 6.1
CONTRIBUTIONS TO GROWTH OF LABOR PRODUCTIVITY
IN THE NONFARM-BUSINESS SECTOR[1]

	1974–95	1995–2004	2004–12
Growth of output per hour[2]	1.56	3.06	1.56
Contributions (percentage points per year)			
Information technology	.77	1.50	.64
IT capital deepening	.41	.78	.36
MFP in IT-producing sectors	.36	.72	.28
MFP outside IT-producing sectors	.13	.90	.06
Other contributions	.65	.67	.86
Non-IT capital deepening	.33	.44	.38
Change in labor composition	.26	.22	.34
Adjustments to MFP growth[3]	.06	.01	.14

SOURCE: Byrne, Oliner, and Sichel (2013).
[1] Detail may not sum to totals because of rounding.
[2] Measured as 100 times average annual log difference for the indicated years.
[3] For effects of adjustment costs and cyclical utilization.

in labor composition. It also identifies the growth contribution from information technology within capital deepening and MFP. The contribution from IT capital deepening measures the increase in output per hour from the *use* of computers and peripheral equipment, software, and communication equipment throughout the economy. By contrast, the contribution from MFP in the IT-producing sector captures the efficiencies achieved by firms that *produce* computers and peripherals, software, communication equipment, and semiconductors. Semiconductors are included in this group because advances in semiconductor technology are the ultimate source of the performance improvements and price declines for IT capital goods.

The first line of the table shows the rapid gains in output per hour over 1995–2004, sandwiched between the two periods of sluggish advances. Much of this variation reflects shifts in the growth contribution from information technology. IT capital deepening was unusually rapid from the mid-1990s to 2004, as was multifactor productivity growth in the IT-producing part of the economy. This was a period of extraordinary advances in semiconductor technology, which led to sharp declines in quality-adjusted prices for computers and communication equipment. Investment in IT capital surged as a result. At the same time, the development of the Internet made this IT capital more productive than when it was used on a largely standalone basis. The rapid decline in the cost of computing power combined with enhanced connectivity spurred far-reaching changes in the way business was done. Two examples were the advent of online retailing and the development of sophisticated inventory-control systems. The efficiency gains resulting from these and other innovations contributed to the hefty rise over 1995–2004 in MFP outside the IT-producing sector of the economy (see Fernald 2015).

Table 6.1 also indicates that IT-related factors explain much of the deceleration in output per hour since 2004. First, the price declines for IT capital goods have moderated, reducing the incentive to invest in this equipment and thus slowing the rate of capital deepening. Second, the IT-producing sector—which accounts for a disproportionate share of MFP growth in nonfarm business—has shrunk as domestic firms have shifted production abroad. Indeed, the share of nonfarm-business output represented by computers and peripheral equipment, communication equipment, and semiconductors has fallen more than 70 percent from its peak in 2000. Third, the most productive uses of the Internet may have been adopted early on, giving way to smaller innovations in recent years. This pattern would be consistent with the historical regularity that innovation comes in waves.

The lower part of the table shows the contributions from all remaining factors—capital deepening for assets other than IT capital, changes in labor composition, and an adjustment to MFP growth to account for cyclical influences. As can be seen, none of these factors varied dramatically across the three time periods, leaving IT as the main force behind both the pickup in productivity growth in the mid-1990s and the slowdown a decade later.

Trends in Semiconductor Technology and Prices

The contribution of information technology to economic growth depends importantly on the improvements in the semiconductor chips embedded in IT capital goods and on the prices of those chips. A stalling out of innovation in the semiconductor sector likely would have adverse consequences for the economy as a whole, as semiconductors are an important general-purpose technology lying

Table 6.2
SEMICONDUCTOR TECHNOLOGY CYCLES
(YEARS NEEDED FOR 30 PERCENT REDUCTION IN LINEAR SCALING)

Industry Frontier		Intel MPU Chips	
Period	**Years**	**Period**	**Years**
1969–93	3.0	1971–94	2.9
1993–2012	2.1	1994–2012	1.9
1993–2003	1.9	1994–2004	1.9
2003–12	2.3	2004–12	2.0

SOURCE: Byrne, Oliner, and Sichel (2013).

behind the advances brought about by the digital revolution, including machine learning, robotics, big data, and massive connectivity. On the other hand, if technological progress and the attendant price declines were to continue at a rapid pace, powerful incentives would be in place for continued development and diffusion of new applications of this general-purpose technology.

There is a broad consensus that the pace of technical advance in the semiconductor industry sped up in the mid-1990s, a development first brought to the attention of economists by Jorgenson (2001). The standard definition of a semiconductor technology cycle is the amount of time required to achieve a 30 percent reduction in the width of the smallest feature on a chip. Because chips are rectangular, a 30 percent reduction in both the horizontal and vertical directions implies about a 50 percent reduction (0.7*0.7) in the area required for the smallest chip component. These scaling reductions are the force behind Moore's law—Gordon Moore's famous prediction that the number of components on leading-edge chips would double every two years.[4]

Table 6.2 reports the average length of the technology cycles for the semiconductor industry as a whole and microprocessor (MPU) chips produced by Intel, the leading firm in the industry. For the industry as a whole, the technology cycle averaged three years until 1993

[4] Moore's original formulation pegged the doubling time at only one year, but in 1975 he revised the period to be two years based on the actual experience to that point. For a discussion of the outlook for Moore's law, see Bauer, Veira, and Weig (2013).

and then dropped to about two years from 1993 to 2012. Within the later period, the scaling advances were especially rapid from 1993 to 2003 and a bit slower after 2003. Even so, the average cycle since 2003 has remained substantially shorter than the three-year cycle in effect before the 1990s. For Intel's MPU chips, there has been no pullback at all from the two-year cycle. The upshot is that the cycles in semiconductor technology—a key driver of quality improvement in IT products—have remained rapid.

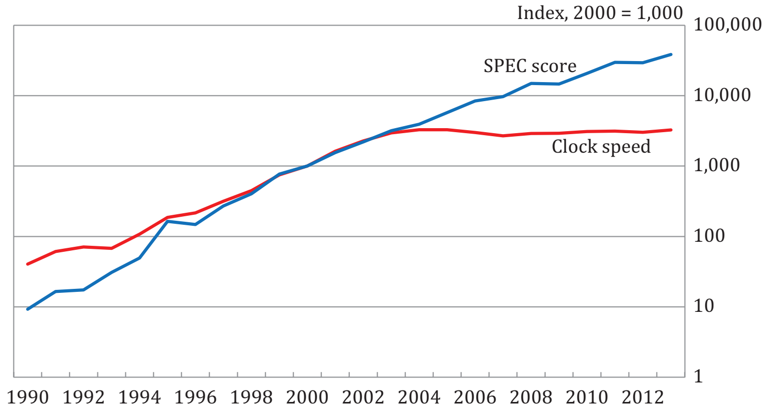
While the pace of miniaturization has been sustained, semiconductor producers have changed the approach used to translate these engineering gains into faster performance. Historically, each new generation of technology in semiconductors has allowed for an increase in the number of calculations performed per second (clock speed) for a given chip design. However, as speed continued to increase, dissipating the generated heat became problematic. In response, Intel shifted away in the early to mid-2000s from increases in clock speed and boosted performance instead by placing multiple copies of the core architecture on each chip and by improving overall chip design.

Figure 6.2 examines the effect of this strategy on the rate of increase in end-user performance for newly introduced Intel desktop MPU chips. The performance scores used to create the figure are from the Standard Performance Evaluation Corporation (SPEC), a nonprofit corporation that establishes performance-benchmark tests for computing equipment and publishes test results submitted by member organizations. The scores are based on standard tasks designed to reflect the needs of computer users. For comparison, the figure also shows clock speed for newly introduced chips.[5]

As shown in the figure, the performance of Intel MPUs has continued to improve even though clock speed stalled out in the early to mid-2000s. SPEC performance rose about 32 percent per year on average from 2000 to 2013, down from the exceptional 60 percent rate of improvement from 1990 to 2000 but similar to the 36 percent pace over the prior 20 years (not shown). Thus, end users have continued to benefit from substantial gains in chip performance.

[5] Unni Pillai kindly provided the data through 1999, which are spliced to data for later years collected by Byrne, Oliner, and Sichel (2015). The annual observations for SPEC score and clock speed are the average across Intel MPU models introduced in each year.

Figure 6.2
DESKTOP MPU PERFORMANCE MEASURES



SOURCE: Authors' calculations using data provided by Unni Pillai and performance information from Intel price lists and SPEC corporation.
NOTE: Figures shown for SPEC score and clock speed are the average across models introduced in each year. Starting in 2004, SPEC score is the "rate" test that incorporates the performance effects of parallel processing.

Given this ongoing dynamism, it is more than a little surprising that the official U.S. government series on MPU prices (the producer price index [PPI] published by the Bureau of Labor Statistics) shows that prices of these chips have barely been falling in recent years. This very slow rate of price decline stands in sharp contrast to the rapid declines in MPU prices reported from the mid-1980s up to the early 2000s and the exceptionally rapid declines in the latter half of the 1990s. If correct, the apparent slowdown in MPU price declines in recent years would be troubling, as it raises questions about whether semiconductor technology can be counted on to keep the prices of IT capital goods on a downward track.

Byrne, Oliner, and Sichel (2015) take a close look at this issue and conclude that MPU prices have been falling much more rapidly in recent years than is indicated by the PPI. To assess the potential bias in the PPI, we construct both hedonic and matched-model indexes of MPU prices using extensive data for Intel chips. Matched-model indexes, including the PPI, control for quality change between two periods by calculating price changes only for models that were in the market in both periods. Hedonic price indexes, in contrast, identify constant-quality price change by explicitly controlling for chip characteristics or performance through an estimated regression.

With a large data set of accurately measured prices, the two methods often yield similar results. But when the data are less than ideal, the results can differ widely. Byrne, Oliner, and Sichel (2015) argue that, given the potential for measurement error in the MPU price data, hedonic indexes are preferable in this market to matched-model indexes—especially hedonic indexes that rely only on prices in the period of a model's introduction (see the paper for details).

Table 6.3 presents the key results from this analysis, which covers the period 2000–2013. Up until 2004, the preferred hedonic index in Byrne, Oliner, and Sichel (2015) and the PPI both fell at a very rapid pace, roughly 50 percent per year. However, the two indexes diverged after 2004. Strikingly, the hedonic index continued to decline almost as rapidly as before 2004, while the decline in the PPI slowed sharply. Indeed, the PPI fell at an average annual rate of only 8 percent from 2008 to 2013 and barely fell at all in 2012 and 2013. For the reasons highlighted in Byrne, Oliner, and Sichel (2015), these results point to likely bias in the PPI for MPUs. The lack of any significant slowdown in the hedonic index suggests that the PPI could be providing a deeply misleading picture of price trends for MPUs in recent years.

These results offer a cautionary note to productivity pessimists at two levels. First, the impetus to growth from the semiconductor

Table 6.3
RATES OF CHANGE IN MPU PRICES
(AVERAGE ANNUAL PERCENTAGE CHANGE OVER PERIODS SHOWN)

	2000–2004	**2004–8**	**2008–13**
Byrne, Oliner, Sichel hedonic index[1]	-55	-47	-49
PPI	-48	-29	-8

SOURCE: Byrne, Oliner, and Sichel (2015).

[1] Based on introduction-period prices using SPEC performance as the control for quality.

sector is not running out of gas. Both the pace of technical advance and the rate of price decline remain rapid. Second, the official government price data for the IT sector should not be taken as gospel. Despite their best efforts, the statistical agencies are always at risk of falling behind the rapidly changing landscape in this sector.

In addition to the apparent bias in the price index for MPUs, the official price index in the National Income and Product Accounts for computers and peripheral equipment looks suspect. Historically these (quality-adjusted) prices have fallen at a rapid clip, pushed down by the steep drop in the prices of the MPUs and other electronic components embedded in this equipment. Between 1959 and 2009, the price index for investment in computers and peripheral equipment fell 16 percent annually on average, and no year had a decline of less than 5 percent. However, in each year from 2009 to 2013, this price index has fallen by less than that amount, and in 2014, the index is on track not to decline at all.

The recent pattern seems highly implausible, especially given the results in Byrne, Oliner, and Sichel (2015) showing that the prices of the embedded MPU chips have remained on a steep downward trend. We believe that the official price index for computing equipment, which is constructed in part with hedonic methods, could be understating the rate of price decline for several reasons, including the failure to control fully for quality improvement. We are in the process of acquiring microdata on computing equipment that will allow us to test this hypothesis.

Looking Ahead

Byrne, Oliner, and Sichel (2013) use the growth-accounting model described above to conduct "what if" exercises for future growth in labor productivity. To do these exercises, we derive the expression for the "steady-state" growth of labor productivity that would hold if the economy were on an equilibrium path. This is an idealized scenario because, in reality, the economy is always being hit with shocks that move it away from the steady state. Nonetheless, the steady state provides a useful laboratory for assessing how productivity growth would vary under alternative assumptions about the key driving factors.

The steady-state expression for growth in labor productivity actually is simpler than the growth-accounting decomposition used above, which measured the contributions from capital deepening, changes in labor composition, and MFP. When we move to the steady state, capital deepening drops out of the decomposition. This happens because the improvement in technology—measured by the rate of MFP growth—determines the amount of capital accumulation. Consequently, in the steady state, growth in labor productivity depends on the rate of MFP growth in each sector of the economy and the change in labor composition.

In the model developed by Byrne, Oliner, and Sichel (2013), steady-state growth in labor productivity depends on a large number of parameters—about 30 in all. The complete list of the parameters, along with their assumed values, can be found in Appendix Table A1 of that paper. Generally speaking, the parameters were set to reflect average values over 1974–2012, except in cases where the latest values were clearly out of line with the longer-period average. For example, by 2012, domestic output of IT hardware as a share of nonfarm-business output had fallen well below the average since 1974. In such cases, we set the parameter value to reflect recent data.

With the parameter values set in this manner, Byrne, Oliner, and Sichel (2013) estimate steady-state growth in labor productivity to be 1.8 percent annually, slightly below the average growth rate observed from 1974 to 2012 but somewhat faster than the average pace since 2004. As shown below, this steady-state estimate about equals the average forecast of labor-productivity growth from other analysts.

We use the same steady-state machinery to consider an alternative scenario that embeds a somewhat more optimistic outlook for information technology. In this alternative scenario, we boost MFP growth in the IT-producing sectors to be roughly halfway between the average pace for 1974–2012 and the more rapid advance during 1995–2004. The resulting lower prices for IT equipment induce greater adoption of new technology, which we assume raises MFP growth in the rest of nonfarm business to the midpoint between the 1974–2012 average and the faster 1995–2004 pace. All other parameters remain at their baseline values.

With these changes, steady-state growth of labor productivity rises at an annual rate of nearly 2.5 percent, almost three-quarters of a percentage point above the baseline estimate. This scenario

Table 6.4
ALTERNATIVE PROJECTIONS OF GROWTH OF LABOR PRODUCTIVITY (PERCENT PER YEAR)

	As of	
	2007	**2014**
Congressional Budget Office	2.3	1.9
John Fernald	n.a.	1.85
Robert Gordon	2.0	1.6
James Kahn and Robert Rich	2.5	≈2.0
Survey of Professional Forecasters[a]	2.2	1.8

SOURCES: 2007 estimates from Oliner, Sichel, and Stiroh (2007), Table 12; 2014 estimates from the Congressional Budget Office (2014), Table 2–2; Fernald (2015), Table 4; Gordon (2014b), baseline forecast of 1.2 percent for total economy, plus adjustment of 0.4 percentage points for translation to nonfarm-business sector; Kahn-Rich Productivity Model Update (November 2014), posted at http://www.newyorkfed.org/research/national_economy/richkahn_prodmod.pdf; Federal Reserve Bank of Philadelphia, Survey of Professional Forecasters, February 14, 2014.

[a] Median forecast in the survey.

illustrates that a substantial, but not historically outsized, pickup in the impetus from IT would lift labor-productivity growth well above its long-term historical average of 2.25 percent, at least for a time. A smaller pickup in the impetus from IT would bring labor-productivity growth up to the long-term average rate. Importantly, a repeat of the IT boom in the second half of the 1990s is not necessary to generate strong productivity growth.

Table 6.4 presents recent projections of growth in labor productivity from several analysts, along with the earlier projections made on the eve of the Great Recession.[6] As shown, the earlier projections of

[6] All of the projections, except Fernald's, refer to horizons of 5 to 10 years, while Fernald's projection is based on a steady-state model and has no explicit horizon. With regard to sectoral coverage, all of the projections are for the nonfarm-business sector or the private business sector. Although Gordon derives his 2014 projection from data for the total economy, I translated that projection to the nonfarm-business sector by adding 0.4 percentage points to his original projection. The adjustment equals the difference in the Congressional Budget Office's projected 10-year growth rates of labor productivity for the total economy and nonfarm business.

the annual rate of growth ranged from 2 percent to 2.5 percent. Between 2007 and 2014, those projections were revised down by about one-half of a percentage point. The latest projections range from 1.6 percent to about 2 percent—better than the actual productivity gains in recent years but below the long-run average. Although Gordon is the most pessimistic of the group, his forecast is not that far below the top of the range. Rhetoric aside, there is not a huge difference among the forecasts that the various analysts have written down.

The relatively narrow range, however, should not be taken to imply a high degree of confidence about the outlook. The Kahn-Rich projection is the only one in the table with a statistically based confidence range. In their regime-switching model, the 75 percent confidence band for productivity growth five years ahead runs from slightly below zero to about 4 percent. Such a wide range is tantamount to saying that the model has nearly no predictive power.

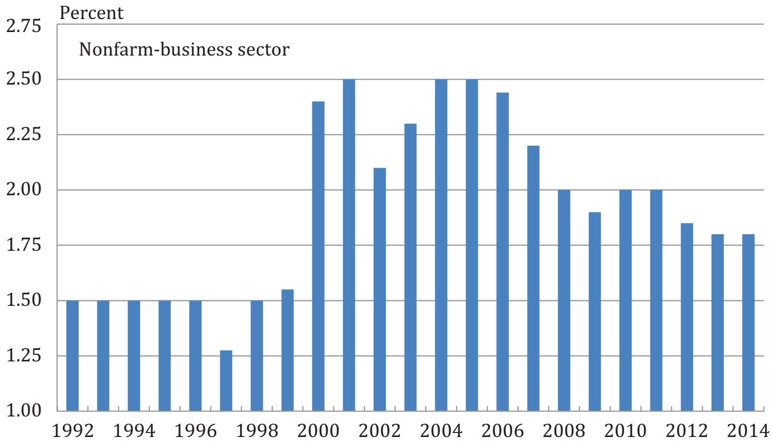
The analysis of long-run predictions in Müller and Watson (2014) comes to about the same conclusion. Using sophisticated statistical methods, Müller and Watson calculate confidence bands for predictions of productivity growth and other economic variables based on the full history of data for each series. They estimate that the 90 percent confidence band for labor-productivity growth in nonfarm business over the next 10 years ranges from 0.6 percent to 3.4 percent. Even the 67 percent confidence band—which, by definition, leaves out a third of possible outcomes—is quite wide, at 1.3 percent to 2.8 percent. Suffice it to say, knowing what productivity growth has been in the past tells us very little about what it will be over an extended period in the future.

Two specific episodes illustrate the difficulty of forecasting productivity growth. As discussed earlier, productivity growth quickened in the mid-1990s and then slowed a decade later. Did economists predict either change in trend? The answer is a resounding no.

Figure 6.3 shows the median forecast of 10-year growth in labor productivity from the Survey of Professional Forecasters. As shown, the median forecast in 1992 expected productivity growth over the coming 10 years to be 1.5 percent, about the average pace since the early 1970s. The median forecast remained at 1.5 percent or below all the way through 1998, indicating that the survey participants as a group not only failed to anticipate the upswing, they did not

Figure 6.3

MEDIAN SPF 10-YEAR FORECAST OF GROWTH IN OUTPUT PER HOUR

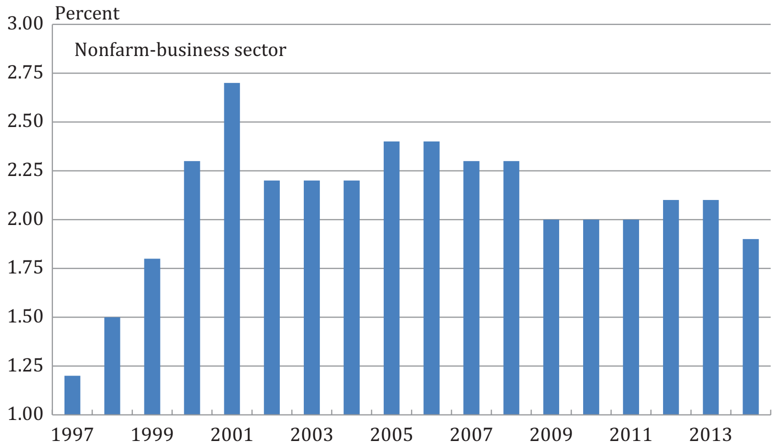


SOURCE: Survey of Professional Forecasters (SPF), Federal Reserve Bank of Philadelphia

NOTE: Each bar shows the median of the 10-year-ahead forecasts provided in the first quarter of the year shown.

Figure 6.4

CBO 10-YEAR FORECAST OF GROWTH IN OUTPUT PER HOUR



SOURCE: Congressional Budget Office (CBO), *The Economic and Budget Outlook*, produced in 1997 and subsequent years.

NOTE: Each bar shows the the 10-year-ahead forecast produced in January of the year shown.

perceive any change in trend until well after the fact. The median 10-year forecast finally jumped in 2000 and hit 2.5 percent in 2001. Despite some year-to-year variation, it remained elevated as late as 2006, showing that the forecasters were unaware of the downshift in growth in 2004 until well after it had occurred.

Figure 6.4 presents the parallel forecasting record for the Congressional Budget Office (CBO), starting with the forecast from 1997 (earlier CBO forecasts are not available). In 1997, the CBO was still forecasting that productivity growth over the next decade would be very weak—less than 1.25 percent at an annual rate. So the CBO, like the private forecasters, did not anticipate the productivity surge. The forecast was subsequently revised upward and remained in the neighborhood of 2.25 percent all the way through 2008 (abstracting from the one-year blip in 2001). Thus, the CBO also did not anticipate the return to slower productivity growth and recognized the shift only with a lag of several years.

None of this should be surprising or be viewed as an indictment of economists. Projecting trend breaks in any economic series is difficult—the economy is simply too complex. Moreover, the task becomes nearly impossible when the data released in real time provide a noisy signal of current developments, with the picture only becoming clearer with subsequent data revisions.

Conclusion

The research discussed in this paper shows that the speedup in productivity growth in the mid-1990s and the return to slower growth a decade later were driven by information technology. The outlook for productivity growth is highly uncertain, and confident predictions should be regarded with skepticism. That said, semiconductor technology has continued to advance at a rapid pace, and semiconductor prices have continued to fall. Thus, the underlying conditions needed for a second wave of the IT revolution are in place. Whether that wave will materialize is, as yet, unclear.

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SECTION THREE

IS ECONOMIC DYNAMISM IN DECLINE?

7. Business Dynamism and Growth[1]

John Haltiwanger[2]

Introduction

A hallmark of the U.S. economy is its economic dynamism and labor-market flexibility. Historically, the United States has exhibited a high pace of simultaneous job creation and destruction. The evidence shows that the high pace of job reallocation has been largely productivity enhancing. That is, it reflects jobs being reallocated away from less productive to more productive businesses. These empirical findings are consistent with theoretical models of firm dynamics that emphasize the importance of creative destruction for innovation and productivity growth.

An important feature of business dynamism in the United States is the role of entrepreneurs. The contribution of entrepreneurs is complex given the tremendous heterogeneity in young businesses. On the one hand, entrepreneurs (as measured by startups and young, high-growth businesses) contribute disproportionately to job creation and productivity growth. Business startups account for about 20 percent of U.S. gross job creation and high-growth existing businesses (which are disproportionately young) account for almost 50 percent of gross job creation.[3] On the other hand, most business startups in the United States exit within the first 10 years and most surviving young businesses do not grow but stay small. Moreover, while the net entry of young businesses contributes to productivity growth, there is a substantial fraction of productivity

[1] This chapter is a synopsis of my recent research on the role of business dynamism in the United States. Without implication to my coauthors, this paper draws heavily on joint work with Steven Davis, Ryan Decker, Lucia Foster, C. J. Krizan, Ron Jarmin, Javier Miranda, and Chad Syverson.

[2] John Haltiwanger is a professor of economics at the University of Maryland.

[3] Haltiwanger, Jarmin, and Miranda (2013) and Haltiwanger (2012).

growth accounted for by growth within existing businesses (including within existing, mature businesses).

The main point for present purposes is that young businesses have been a key part of the business dynamism that has contributed substantially to job creation and productivity growth in the United States. A source of concern is that the pace of business dynamism has fallen in the United States over the last couple of decades with an acceleration in the post-2000 period. The decline in business dynamism has been accompanied by (and indeed proximately caused by) a decline in the pace of entrepreneurship.

As discussed in the recent literature (see in particular Decker et al. 2014a, 2014b, and Davis and Haltiwanger 2014), the decline in entrepreneurship and business dynamism has changed character since 2000. Prior to 2000, much of the decline in entrepreneurship and business dynamism was concentrated in sectors such as retail trade and services. In those sectors, there has been a substantial change in the business model away from small, single-establishment firms ("mom-and-pop" firms) and toward large national chains. The establishments and firms from the latter are both more stable and productive than the former. Accordingly, before 2000, this shift in the business model may have enhanced rather than adversely impacted U.S. productivity growth. However, since 2000, such key innovative sectors as high tech have seen a decline in entrepreneurship and business dynamism as well. During this same period of time, U.S. aggregate productivity and job growth have been anemic (even prior to the Great Recession), which raises the obvious concern that the anemic aggregate performance is associated with this decline in entrepreneurship and business dynamism.

Conceptual Underpinnings

Empirical evidence shows wide dispersion in profitability and productivity within industries (Syverson 2004). The extent of this dispersion is surprising, raising the question about why low and high productivity/profitability firms coexist in the same industry. One view is that the observed dispersion reflects the frictions and perhaps distortions present that prevent resources from being immediately allocated to the most productive firms. A related idea is that there may be sources of curvature in the profit function such that the most productive firms do not take over the market. Lucas (1978) yields an equilibrium size distribution of firms by emphasizing the interaction of heterogeneous entrepreneurial ability with the span of control. An alternative means of generating an equilibrium size distribution within an industry is to assume the curvature in the profit function derives from a differentiated product environment.

With this wide dispersion of productivity and profitability as a backdrop, there is a rich set of models that help us understand the observed industry and firm dynamics. Jovanovic (1982) posits that at entry firms do not fully know their productivity (or other aspects of profitability) and so an important part of firm dynamics, especially for new or growing industries, is the selection and learning dynamics of young firms. Those firms that learn they have a good location, or a good product or process, survive and grow. Those that learn they are not profitable contract and exit. Ericson and Pakes (1995) push further on this idea by arguing that every time a firm makes a major change in its way of doing business (either by adopting a new technology or responding to such a major change in economic conditions as higher energy costs), the firm gets a new draw on its profitability and productivity with associated selection and learning dynamics.

The more general notion as illustrated in models such as Hopenhayn (1992) and Hopenhayn and Rogerson (1992) is that firms are subject to new profitability shocks in any given period. Shocks are persistent, but technical efficiency, demand, and cost conditions are stochastic. Viewed from this richer perspective, firms are forced to adjust and adapt to changing economic circumstances. While their past successes can help in forecasting their ability to adjust and adapt, firms are regularly required to reinvent themselves. Those firms that reinvent themselves successfully survive and grow; those that cannot adapt and adjust to changing economic conditions contract and exit.

In these models, productivity is closely tied to creative destruction. Well-performing economies are those where resources are being reallocated from less productive to more productive businesses on an ongoing basis without too much disruption and associated costs.

The potential contribution of creative destruction to growth is enhanced further in models such as that of Acemoglu and coauthors (2013), in which innovation is endogenous. In the latter model, it is assumed that young firms are those that are more likely to make major innovations. Accordingly, the entry and exit of businesses are critical for major innovations to occur.

This short review of the literature has one main punch line for present purposes. Given the tremendous dispersion in productivity across businesses for exogenous and endogenous reasons, it is critical that the pace of business dynamism act to move resources to their highest-valued use. Many factors may distort and slow down these dynamics. The open question is whether distortions and frictions in the United States account for the observed slowdown in business dynamism.

Cross-Section Evidence: Understanding the Past

The discussion of conceptual underpinnings above highlights the importance of entry and exit and reallocation in productivity dynamics. We now turn to briefly summarizing what role startups and young businesses play in job creation and productivity growth in the United States.[4]

It is useful to begin by discussing long-run averages. First, consider the contribution of startups and young businesses to job creation in a period of robust net job growth. Since the United States is still recovering from the Great Recession, we initially focus on the period prior to the Great Recession. The U.S. economy had very robust net employment growth in the second half of the 1990s (March 1994 through March 2000). During this period, net job creation in the U.S. private sector over the course of the year was approximately 2.9 million jobs per year.[5] In this same period, startups (new firms) in the private sector accounted for over 3 million jobs per year. From this perspective alone, startups are an important contributor to job creation. As we discuss below, the entrepreneurship rate has declined in more recent years. For example, in 2011, even though the size of the workforce had grown considerably since the late 1990s, the contribution of startups to net job creation was only 2.5 million. Overall net job creation in 2011 was 2.6 million. Employment by startups as a fraction of total employment has been about 2 percent recently, compared to

[4] This section builds on Haltiwanger, Jarmin, and Miranda (2013) and Decker et al. (2014a, 2014b) in terms of broad themes. This will become clear as that work is repeatedly cited in this section. However, this section also highlights findings that distinguish between establishment and firm dynamics and the associated distinction between young establishments and young firms.

[5] See Decker et al. (2014a, 2014b) for details.

averaging over 3 percent in the late 1990s. This represents a substantial decline in the startup rate.

The contribution of startups to job creation does not stop at entry. Young firms in the United States exhibit an up-or-out dynamic. Most young firms exit. However, conditional on survival, young firms have much higher growth rates than more mature firms. Five years after the entry of a typical cohort, total employment by surviving firms is about 80 percent of the original contribution of the cohort. Thus, the long-lasting contribution of startups to job creation is due to the relatively small fraction of young firms that grow rapidly.

The high mean net growth of surviving young firms masks enormous heterogeneity among young surviving firms. Evidence for this is reported by Ryan Decker and coauthors (2014a). They show (see Figure 2a of that paper) that young firms have very high dispersion of growth but also very high skewness of growth. The skewness accounts for the very high mean growth rates of surviving young firms as seen in Figure 3 of Decker and coauthors (2014a). Decker and coauthors (2014a) also show that young firms (and for that matter essentially all firms) exhibit median growth rates close to zero. Their findings highlight that the typical young firm (as captured by the median) exhibits little or no growth even conditional on survival. However, the skewed right tail of young firms shows that young firms disproportionately account for high-growth firms.

Startups and the high-growth firms that yield the skewness in growth rates contribute disproportionately to job creation. Decker and coauthors (2014a) show that startups account for less than 10 percent of firms but more than 20 percent of gross job creation. High-growth firms (defined here as firms growing more than 25 percent per year) account for about 15 percent of firms and 50 percent of gross job creation. High-growth firms are predominantly young firms: 65 percent of the high-growth firms are less than 10 years old.[6]

Overall, the evidence shows that startups are small, most fail, and conditional on survival most do not grow. But among the surviving

[6] High-growth young and mature firms are both important contributors to job creation. High-growth young firms contribute 51 percent of the job creation from all high-growth firms. The important contribution of high-growth mature firms reminds us that there are rich dynamics even among mature firms in a manner consistent with Ericson and Pakes (1995).

startups are high-growth firms that contribute disproportionately to job growth.

These dynamics have important implications for productivity growth (see Syverson 2011 for a recent survey). Common findings are that exiting businesses have much lower productivity than incumbents and that, among surviving firms, those with higher productivity exhibit faster growth. These patterns underlie the finding that the reallocation of outputs and inputs away from low-productivity to high-productivity businesses is important for productivity growth.

Declining Trends: The Present and the Future?

We turn now to trends in business dynamism over time. Summary measures, such as the pace of job reallocation and entrepreneurship, have exhibited a secular decline that dates back to at least the 1980s.[7] Since the U.S. economy experienced robust net job and productivity growth through much of the second half of both the 1980s and 1990s, this might suggest that the decline in dynamism and entrepreneurship may have benign underpinnings. Indeed, as discussed in the introduction, the decline in dynamism and entrepreneurship was disproportionately accounted for by the retail and service sectors in the 1980s and 1990s. The most prominent explanation for the decline in retail is the growth of large, national chains that have taken advantage of globalization and information technology. The evidence suggests that this has been productivity enhancing for the retail-trade sector (see Foster, Haltiwanger, and Krizan 2006). The reallocation that has occurred in that sector has largely been from exiting mom-and-pop establishments to the entering establishments of large, national chains.

Prior to 2000, dynamism and entrepreneurship were growing in sectors such as high tech. Dynamism was also rising among publicly traded firms for related reasons. In the 1980s and 1990s, initial public offerings (IPOs) accelerated. Many of these were in the high-tech sector, and the 1980s and 1990s cohort of IPOs exhibited very rapid growth after going public. Strikingly, the 1990s cohort of IPOs grew so fast that this cohort accounted for most of the activity among

[7] See Davis et al. (2006), Decker et al. (2014a, 2014b), and Hyatt and Spletzer (2013) for recent evidence on these trends. This section borrows heavily from the findings in Decker et al. (2014a, 2014b).

publicly traded firms by the year 2000. Another feature of U.S. economic dynamism that was robust in the pre-2000 period was the contribution of high-growth young firms. This was evident through the substantial differential between firms at the 90th and 50th percentiles of the growth-rate distribution for young firms.

All of this began to change around 2000, as recently documented by Decker and coauthors (2014b). Dynamism and entrepreneurship in the high-tech sector began to decline. Some of this represented the collapse of the dot-com boom in the late 1990s, but the decline continued over the next decade. Dynamism and entrepreneurship in high tech in the mid-2000s were at a substantially lower level than in the mid-1990s. Dynamism in the publicly traded sector also started to decline around that time and has declined over the course of the post-2000 period due both to a drop in the number of IPOs and a decline in the rapid growth of new publicly traded firms. High-growth young firms also declined. The 90–50 differential in the growth rates of all firms and especially young firms fell dramatically in the post-2000 period—enough so that by 2011 the positive skewness that characterized the distribution of young firms had virtually disappeared.

What brought about the post-2000 slowdown in entrepreneurship and dynamism? That is an open question. It is critical to determine whether the slowdown represents a change in the business model of growth dynamics (such as occurred in retail trade) or rather increasing distortions and frictions that accelerated in the post-2000 period. As we noted earlier, an increase in adjustment frictions or distortions can slow down these dynamics and contribute adversely to economic growth.

One factor that appears to be important in accounting for poor entrepreneurial performance in emerging economies is the incomplete development of capital markets for providing credit to young and small businesses. While the United States has the most advanced development of capital markets overall, the financial crisis may have contributed to the decline in entrepreneurial activity in the United States by reducing new firms' access to credit. Consistent with this view, the evidence shows that young and small businesses were hit especially hard in the Great Recession.[8] However, the overall decline in entrepreneurship and high-growth young firms after

[8] See Fort et al. (2013).

2000 predated the crisis. In that respect, the financial crisis can be viewed as insult added to injury.

There is also evidence that adjustment costs for employment have risen in the United States. For example, Davis and Haltiwanger (2014) highlight two factors that have worked in this direction. They note that there has been erosion of the employment-at-will doctrine through court cases, and they show that this erosion is related to the decline in job reallocation. They also highlight the recent evidence from Kleiner and Krueger (2013) that shows that the share of jobs that require some type of occupational licensing has grown dramatically in the last few decades—from roughly 10 percent in 1970 to almost 30 percent today.

Finally, Decker and coauthors (2014b) provide indirect evidence that the decline in dynamism likely reflects increased adjustment frictions. They present microevidence that businesses are becoming less responsive to productivity shocks in terms of growth and survival. Moreover, they show that the declining responsiveness to shocks accelerated in the post-2000 period. They also show that, if anything, the dispersion of idiosyncratic productivity shocks has increased over time. The implication is that reallocation has fallen not because of declining shocks but because of declining responsiveness to shocks.

Concluding Remarks

In the United States, startups and young firms have historically been important contributors to job creation and productivity growth. But the process of that contribution is quite complex. While startups contribute substantially to jobs immediately, most startups fail. Of those that survive, most do not grow. But among surviving young firms is a relatively small share of very high-growth firms that contribute substantially to job growth. These high-growth young firms are responsible for the fact that overall net-growth rates of surviving firms decline with firm age even though the median young firm does not grow. Put differently, high-growth young firms yield considerable positive skewness in the distribution of surviving young firms.

Evidence shows a tight relationship between these growth and survival dynamics and productivity as well as with measures of profitability. For any cohort of recent entrants, those with low productivity and profitability are much more likely to exit than other firms. In contrast, young firms with higher levels of productivity and profitability grow more rapidly.

The pace of business dynamism and entrepreneurship has declined in the United States over the last few decades with an acceleration in the post-2000 period. The acceleration of the decline preceded the Great Recession, but the latter has also had an adverse impact on young firms. The character of the decline also changed in the post-2000 period. Before 2000, the decline in reallocation and entrepreneurship was disproportionately in retail trade and services. At least some of this reflected a change in the business model—especially within retail trade, given the shift away from mom-and-pop to large national-chain firms. The latter are more stable and more productive, so in this respect part of the decline in dynamism over this period likely reflected benign factors. But after 2000, entrepreneurship and dynamism have declined sharply in the high-tech sector and among publicly traded firms. There has also been a decline in high-growth young firms.

What underlies the decline in the post-2000 period? This remains an open question. However, the evidence suggests it is not due to declining volatility of shocks impacting firms but rather declining responsiveness to shocks. The decline in dynamism in the post-2000 period is associated with a period of more anemic job and productivity growth. In addition, recent studies show this decline in dynamism is associated with a broader decline in labor-market fluidity (see Davis and Haltiwanger 2014). Specifically, there has been a slowdown in the pace of both overall worker reallocation (hires plus separations) and job-to-job flows (workers directly moving from one firm to another). The broader decline in fluidity is also associated with a drop in the employment-to-population ratio.

Putting all of this together, the decline in business dynamism has been accompanied by more anemic job and productivity growth, less labor-market fluidity, and a decline in labor-force participation rates. Causality remains an open question, but it is difficult to argue that the United States remains the highly dynamic, flexible economy that it was during the 1990s.

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8. The Demise of U.S. Dynamism Is Vastly Exaggerated—But All Is Not Well[1]

Amar Bhidé[2]

Good tidings: discouraging estimates of slowing productivity growth should not be a cause for alarm, as the venturesome foundations of our economy seem largely intact. But the skies are not cloudless: while opportunities to innovate and to enjoy the fruits of innovations remain abundant for most, they may have diminished for more than a few.

My guardedly optimistic assessment derives from numerous but potentially unrepresentative observations. I study the anatomy and physiology of enterprise, not its epidemiology, and focus more on healthy specimens than on pathologies. But while we should always treat generalizations inferred from particular observations as provisional, we can legitimately question statistics that conflict sharply with such generalizations. Health authorities don't track the number of people running a temperature. Unlike some ancient Greeks, we don't confound fever as a symptom with a disease in itself or attribute the condition to overheated or putrefied humors, as did Hippocrates and Galen.[3] Similarly, an appreciation of the complexity of enterprise predisposes me to discount estimates of productivity derived from reductive models akin to the four humor theories of disease. Data on new-business formation and growth seem more troubling, however.

[1] This chapter draws heavily on my earlier work on entrepreneurship and innovation, most notably Bhidé (2000) and Bhidé (2008).

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[3] According to Sajadi et al. (2012, p. 976), "Early Greek texts did not distinguish between fever as a sign and fever as a symptom. Likewise, early on, there was an overlap between the sign or symptom of fever and Fever the disease." They note that Galen did later clearly distinguish between the symptom of fever and its underlying diseases but continued to rely on humor-based explanations.

My argument proceeds in the following sequence. I first discuss how innovation became more broad-based (and less destructive) during the 20th century as more diverse organizations harnessed the increased enthusiasm and capacity of more individuals to engage in innovative activity. I then critique the utility of productivity estimates because they assume a monolithic, mechanistic process of innovation that is fundamentally incompatible with the widespread exercise of human agency and imagination. Finally, I discuss why data indicating the deteriorating performance of what I have called "promising" new businesses (Bhidé 2000) and David Birch had previously called "gazelles" warrants real concern.

I will avoid debating whether we are on the verge of new technological and scientific breakthroughs.[4] I have no capacity for such prognostication. Furthermore, my observations suggest there are ample opportunities to innovate using the existing stock of scientific and technological knowledge, particularly in services that now comprise nearly two-thirds of gross domestic product.

Broad-Based Innovation

Capitalism has long been technologically progressive, as Marx put it. But, in the 19th and early 20th centuries, contributions to advances were not broad-based. Although many revolutionary products were invented between 1850 and 1900, the new artifacts were usually developed by a small number of inventors and sold to a few wealthy buyers. Alexander Graham Bell invented the telephone with one assistant. Automobile pioneers were one- or two-man shows—Karl Benz and Gottlieb Daimler in Germany, Armand Peugeot in France, and the Duryea brothers of Springfield, Massachusetts. And small outfits couldn't develop products for mass consumption. The early automobiles were expensive contraptions that couldn't be used for day-to-day transportation because they broke down frequently and lacked a supporting network of service stations and paved roads. One or two brilliant inventors couldn't solve these problems on their own.

Innovation became more broad-based in the 20th century. The Internet does not have a solitary Alexander Graham Bell. Innumerable entrepreneurs, financiers, executives of large companies,

[4] Erik Brynjolfsson and Andrew McAfee (2013) and Joel Mokyr (2013) take the optimistic side of this debate. Gordon (2014a) offers the pessimistic view.

members of standard-setting institutions, researchers at universities and commercial and state-sponsored laboratories, programmers who have written and tested untold millions of lines of code, and even investment bankers and politicians, and not just a few visionaries or researchers, have turned the Internet into a revolutionary medium of communication and commerce. Steve Jobs, often portrayed as a brilliant solitary inventor, relied on the contributions of tens of thousands of individuals working at Apple Inc. and its network of suppliers. And harnessing the creativity and enterprise of the many rather than of a few results in more, better, and faster innovation.

The democratization of what I have called venturesome consumption also now plays a critical role. Unlike the rich hobbyists who bought the early automobiles, millions of the not-so-well-to-do scoop up products such Apple's iPad and Microsoft's Kinect (the fastest-selling consumer device ever) from the get-go. And, while consumers get the lion's share of the value created by new products—more than 95 percent according to Nordhaus's (2005) estimates[5]— they are not passive beneficiaries of a windfall as Romer (2007) claims.[6] Buying a new product involves a leap of faith and using it effectively often requires resourceful effort: we cannot know in advance whether a new product is safe and worth the price; few products, iPads and iPods included, "just work" out of the box; we have to learn about their quirks and features and adapt them to our particular needs. In fact, the total time and money that users invest in selecting, installing, learning about, and tweaking new products may well swamp the labor and investment of the developers of the products. But, without consumers willing to try and learn how to use new things, few new things would be developed, produced, and used.

[5] Other studies reporting (or implying) large consumer surpluses include Mansfield et al. (1977), Bresnahan (1986), Trajtenberg (1989), Hausman (1997), and Baumol (2002).

[6] According to Romer, innovators "have brought the cost of a transistor down to less than a millionth of its former level. Yet, most of the benefits from those discoveries have been reaped not by the innovating firms, but by the users of the transistors. In 1985, I paid a thousand dollars per million transistors for memory in my computer. In 2005, I paid less than ten dollars per million, and yet I did nothing to deserve or help pay for this windfall."

Nondestructive Creation

Innovation has also become more balanced between its destructive and nondestructive manifestations and therefore more economically sustainable.[7] "Creative destruction" may well have dominated in the 19th century as tractors displaced plows, steamships displaced sailboats, and railroads displaced stagecoaches. But while creative destruction continued through the 20th century, a significant proportion of 20th-century innovations did not displace existing products—rather, they created new markets and satisfied new wants. Air conditioners reduced temperatures in previously uncooled factories, stores, and office buildings. Airplanes did not reduce the demand for automobiles—people flew when they would not have driven. New drugs and vaccines offered cures for diseases for which treatments did not previously exist. In 1938, the *New York Times* lamented that the typewriter was "driving out writing with one's own hand," yet global consumers continue to buy some 14 billion pencils annually, enough to circle the world 62 times.[8]

Moreover, even those apparently destructive new products also created new markets because of features that satisfied a different set of wants than did the products they made obsolete. For instance, mass-produced automobiles provided not only cheaper but much faster transportation than did horse carriages, so people could live in spacious houses located at some distance from their workplace. Automobiles thus helped create a market for commuting (and suburban housing) that did not previously exist.

The symbiotic relationship between creative destruction and nondestructive creation has helped sustain the pace of innovation. We could not continue to increase living standards simply through new products or technologies that satisfy existing wants at lower cost. Sure, as costs decline, people will consume more of the good or service. But eventually, the law of diminishing returns will set in and sated consumers will refuse to buy more even if prices continue to decline. And once demand for goods levels off, further increases in production efficiencies will reduce the demand for labor.

[7] This section summarizes a lecture I gave at the Royal Society of Arts in London on November 17, 2004. See also Chapter 13 of Bhidé (2008).

[8] Petroski (1990).

Creative destruction has not unleashed mass unemployment—or provided the mass leisure predicted by John Maynard Keynes—because of nondestructive innovation. Creating and satisfying new wants uses the labor and purchasing power released by increased efficiency in the satisfaction of old wants. It also stimulates increases in efficiencies even after demand for old wants has been fully satisfied: producers who satisfy old wants have to keep economizing on their use of labor because they must compete for employees (and share of consumers' wallets) against innovators who satisfy new wants.[9]

Organizational Diversity and Techniques

More broad-based (and less destructive) innovation was helped along by diverse forms of organization. In the 19th century, exceptional individuals with all-around talent undertook innovations through simple partnerships or small firms. The more diverse organizations that emerged in the 20th century could harness the collective efforts of individuals with more specialized or less exceptional talent.[10]

As business historian Alfred Chandler has shown, large, professionally managed corporations, which appeared in the last half of the 19th century,[11] became a major force for developing and deploying innovative products in the 20th century. Companies such as DuPont, for instance, developed new materials, such as nylon, in their research labs, produced them on a mass scale at low cost, and created large markets for their use. In other words, large corporations were adept at orchestrating innovations by the many and for the many.

[9] Even if new products are manufactured abroad, nondestructive innovation helps maintain employment by creating new domestic jobs to transport, advertise, market, install, and maintain the new products. In many cases, the value added and employment generated through these activities is greater than from making the products themselves. For instance, although computers are now largely produced abroad, their sales, marketing, transportation, and installation account for about half the purchase price. Expenditures on the staff necessary to support the computers can amount to six times the purchase price. Arguably, the growth in the range of products we consume has been an important contributor to the growth in the proportion of service-sector employment.

[10] I discussed the comparative advantages of different organizational forms in considerable detail in Bhidé (2000, 2008).

[11] Chandler (1990, p. 1).

By the 1960s, large corporations had become ubiquitous, producing nearly half the goods and services annually available in the United States. This more oligopolistic structure favored less destructive innovation. Many behemoths had come to dominate their markets by exploiting economies of scale and scope to displace small businesses. These economies then became formidable barriers to their own displacement. Creating and serving new wants offered better prospects to the innovator except in markets (such as retailing) that remained fragmented. In some instances, as the work of Clayton Christenson has shown, innovators who initially satisfied new wants and underserved customer segments later became threats to large incumbents. But entrepreneurial Davids successfully hurling slingshots at Goliaths from the get-go were virtually unknown.

Nonetheless, opportunities for nondestructive innovation and the transformation of the still-sizable fragmented markets allowed classic entrepreneurship to continue to flourish. Great enterprises such as Hewlett-Packard, Xerox, Polaroid, McDonald's, and Walmart were started in an era when large incumbents were considered omnipotent.

By the early 1980s, professionally managed venture-capital (VC) funds began to see explosive growth, and the firms they invested in came to be regarded as the new standard-bearers of innovation. The once-hot large corporation was regarded as passé and on the path to eventual extinction. In fact, the emergence of VC-backed businesses also represented an increase in the diversity of organizational forms rather than creative destruction. Just as large corporations did not make the classic self-financed entrepreneur obsolete, VC-backed businesses did not knock out large corporations. Rather, different types of organizations specialized in different innovative activities and complemented each other's capabilities.

The new organizations that emerged in the 20th century developed new management techniques to help them develop, make, and sell new products and services. In the first half of the century, as Alfred Chandler has documented, top managers of large companies such as General Motors evolved a systematic approach to decide what innovations to undertake. The development of the wide range of management techniques that followed further increased the efficiency and scope of broad-based innovation. Project and supply-chain management techniques, for instance, facilitate the integration of large teams of individuals with specialized expertise within and across organizations. Continuous improvement and "six-sigma" techniques harness the creativity and initiative of rank-and-file employees—in complete repudiation of the Fordist principle of specifying the tasks of assembly-line workers in the minutest possible detail.

Consumer surveys, focus groups, and now design-thinking tools seek to anticipate the nature and extent of new wants to reduce the incidence of failed product launches and the iterations necessary to satisfy customers. And new marketing and sales techniques help stimulate latent or inchoate wants and—this is particularly important as products and features proliferate—help match buyers with products and educate them in their effective use.[12]

Individual Will and Capacities

A greater willingness—and capacity—of individuals to help develop and deploy innovations has complemented the ability of organizations to undertake innovations. Besides the traditional regard for qualities such as self-improvement and a can-do spirit, other attitudes and beliefs that now undergird innovation have a distinctively modern, late 20th-century character,[13] including the following:

- *Expectations of rapid technological change* have become widespread. In earlier times, a relatively small number of people—mostly visionary inventors and scientists—believed in the inevitability

[12] Many of these techniques were developed by large companies. IBM pioneered a systematic approach to selling large-ticket systems. Six sigma was first implemented in the United States by Motorola and popularized by General Electric. Large companies are also the most strongly wedded to their use, creating the impression that these techniques hinder innovation. In fact, however, development projects that use large teams simply cannot be undertaken without rules and organization. Nor can complex systems be sold without the sort of sales process pioneered by IBM. Below the apparently freewheeling open-source development of Linux lie elaborate processes and rules and, yes, a hierarchy. To play in the big leagues, even companies that start off with no management to speak of, such as Microsoft, have to routinize their approach—and hire managers from large companies to oversee the new routines. Venture capital–backed companies hire executives from large companies to implement (albeit with suitable adaptation) systematic managerial processes from the get-go. And thanks to the acceptance of job hopping, high-potential startups can attract the experienced executives they need.

[13] See Bhidé (2008, pp. 389–92), for a more complete discussion.

and desirability of technological progress. Now, many believe they can prosper by pursuing the next New Thing and that if they don't, they will fall behind. And the widespread expectation of the inevitability of rapid scientific and technological progress helps make it a self-fulfilling prophecy.[14]

- *Gratification from early adoption*. Consumers who often aren't flush with cash rush to buy expensive new gizmos, such as 3-D TVs, despite knowing prices will soon drop and reliability will increase, because they derive utility from early adoption. The gratification that many modern consumers enjoy may be contrasted with the "conspicuous consumption" undertaken in the Gilded Age, according to Thorstein Veblen, to demonstrate wealth: today's early purchasers seek to display technological sophistication rather than wealth (which they may not even pretend to have).
- *Reduced regard for thrift* has supported the more democratized buying of cutting-edge products. Through the end of the 19th century, according to Max Weber's thesis, religious convictions about thrift sustained the "spirit of capitalism."[15] But today, because venturesome production requires venturesome consumption, excessive thrift can injure rather than help capitalism. As it happens, modern consumers have been more inclined to keep up with (if not stay ahead of) the recently acquired baubles of their neighbors than to display excessive thrift.
- *Eroding aspirations for long-term employment.* Although relatively few people actually enjoyed lifelong employment at high wages, many once hoped to; starting and retiring at IBM or General Motors was considered a good thing. Now, employees often regard job hopping as necessary for getting ahead, and employers don't look down on well-traveled résumés or reward extended loyalty. Job hopping can in turn lubricate innovation by improving

[14] Consider Intel cofounder Gordon Moore's famous observation that the number of transistors built on a chip doubles every 18 months. Semiconductor companies who believe in this so-called law invest the resources needed to make it come true. Device and software producers design products in anticipation of the 18-month cycle. So when new chips arrive, they find a ready market, which in turn validates beliefs in Moore's law and encourages even more investment in building and using new chips.

[15] Weber argued that merchants and industrialists accumulated capital in the belief that they had a moral duty to strive for wealth as well as to lead austere lives.

> the matching and rematching of individual talents and teams[16] and by helping to disseminate knowledge of innovative techniques. Job hopping helps disseminate the know-how necessary to effectively use new technologies. Walmart, for instance, has been a leader in using technology to manage its supply chain. Its alumni have helped propagate Walmart's expertise not only to its direct competitors but also to online retailers such as Amazon.[17]

The expansion of tertiary education ("attending college"), especially after World War II, has given more individuals a greater capacity to innovate. Some argue college educations are a waste for many who attend. Charles Murray, for instance, claims that only a minority of people whose intelligence is well above average benefit from higher education.[18] In my view (Bhidé 2008, pp. 398–402), the democratization of higher education has provided subtle advantages. College graduates may not retain much of what they learn, and technical knowledge now often becomes quickly obsolete. But college curricula, which are invariably more kaleidoscopic than those at vocational schools or technical apprenticeships, offer benefits: they require students to quickly familiarize themselves with a wide range of often-unrelated subjects. This can improve both the ability—and equally importantly the confidence—to learn new things. And college students generally have to communicate and cooperate with a more diverse set of fellow students than they had previously encountered in their high schools or whom they might encounter in a vocational school. This kind of socialization can also help individuals participate in teams comprising a set of diverse and unfamiliar characters assembled to undertake innovative projects.

[16] According to AnnaLee Saxenian, for instance, the high propensity of employees in Silicon Valley to change jobs results in "spontaneous regroupings of skill" that place high-quality employees in high-potential ventures. See Saxenian (1994), cited in Postrel (2005).

[17] Footloose employees are also more likely to support the purchase of unproven new products (for their private gratification or otherwise) because they don't expect to be around if the products ultimately fail.

[18] A college education "makes sense for only about 15% of the population," or at a stretch, 25 percent, Murray states. "For learning many technical specialties," writes Murray, "four years is unnecessarily long." See Murray (2007).

Conflicting Evidence

Views from the trenches and from up high provide strikingly different assessments of the state of dynamism. The former suggests that the underpinnings and pace of innovation have not weakened. Many of the enabling factors I have discussed above gathered speed long after the 1970s, when pessimists say economic sclerosis set in. As mentioned, professional venture capital became a force after the early 1980s. Harnessing the creativity and enterprise of rank-and-file employees caught on in the 1980s when managers of struggling U.S. companies sought to emulate their Japanese rivals and such books as *In Search of Excellence* (1982) and *Theory Z: How American Business Can Meet the Japanese Challenge* (1981) became best sellers. The participative ethos was systematized through quality circles and six-sigma programs during and after the 1990s. The declining aspiration for secure jobs and a corresponding increase in free agency is also of recent vintage. The wrenching recession of the early 1980s was a turning point in making lifetime employment a matter of short-term convenience. Continuing pressure from Wall Street and global competitors, especially from Asia, intensified the trend. And although the building blocks of professional sales and marketing date back to the 1940s, the use of design thinking, which seeks to connect users and developers more effectively, is said to have entered the business world with the founding of IDEO in 1991.

Concrete outcomes also suggest the pace of innovation has not abated. Any number of today's quotidian artifacts would have been unrecognizable, perhaps unimaginable, a decade ago. Routine dealings with supposedly hidebound government agencies, from paying tolls and taxes to renewing drivers' licenses, have been transformed by digital technologies. Professors may receive life sentences, but students look forward to many twists and turns in their careers. And marquee employers shine and fade. Digital Equipment, Compaq, Sun Microsystems, and Netscape are gone. LinkedIn is in, as are Amazon, Google, and Facebook.

The pessimistic claim that our best days are behind us derives from macrodata, primarily on estimates of labor and total factor productivity (TFP). According to Gordon (2014a), "epochal" inventions of the Second Industrial Revolution, which continued to bear fruit through the first six decades of the 20th century, sustained a 2.36 percent rate of labor-productivity growth (output per hour worked) between 1891 and 1972. Growth in output per hour worked slumped to 1.38 percent per year from 1972 to 1996, and after accelerating briefly (to 2.54 percent per year from 1996 to 2004) fell back to growing at just 1.33 percent per year from 2004 to 2013.

Estimates of the growth of TFP—intended to reflect the efficiency of converting both labor and capital into goods and services—reinforce the pessimistic view. According to estimates reported by Gordon (2014b), the rate of growth of TFP fell even more sharply than labor productivity after 1970 (see Table 8.1).

Table 8.1
PRODUCTIVITY GROWTH

	Annual Growth Rate (%)	
Period	**Labor Productivity**	**Total Factor Productivity**
1890–1920	1.50	0.59
1920–70	2.82	1.84
1970–2014	1.68	0.63

SOURCE: Gordon (2014b).

On the surface, the doleful macroevidence appears more credible. Inferences derived from stories of successful innovations are subject to confirmation and vividness biases. Productivity estimates should in principle provide more objective markers. We should particularly privilege TFP, which, according to Gordon and many other economists, represents the best possible measure of innovation: if the same capital and labor inputs produce more goods and services, we may plausibly credit innovation. But as we will see next, how inputs and outputs are measured and productivity is actually estimated undermines the inferences we can draw.

Implausible Indicators

The myriad problems of estimating productivity are well known.[19] I will highlight three ways in which productivity estimates ignore basic features of modern innovation that I described earlier.

[19] Coyle (2014) provides a comprehensive review of the limitations of using inflation-adjusted gross domestic product as a measure of economic output.

First, measures of outputs and inputs disregard much of what users get and give. As is well known, using market prices to measure outputs (GDP) eliminates consideration of the value consumers derive in excess of what they pay for their purchases. If typical estimates of the consumer surplus generated by innovations are right, conventional measures of output growth fail to capture possibly 90 percent or more of the value of innovations. The undercounting is particularly extreme in the Internet era, when consumers receive so much information for free, as Brynjolfsson and McAfee (2013) and Mokyr (2013) have pointed out. Symmetrically, input measures ignore the money and virtually all the labor invested by venturesome consumers. As mentioned, the uncertain utility of new products makes their acquisition a risky outlay, and the effective deployment of many new products can require considerable effort. But user investment isn't counted at all (because it is an opportunity cost) or recorded as consumption or current expenditure.

Second, estimates of the "real" or inflation-adjusted changes in inputs and outputs ignore innovations that change what we consume. Nondestructive innovation that satisfies completely new wants clearly precludes comparing the prices of identical consumption baskets over time. Innovation muddles price comparisons even of goods and services that satisfy existing wants. Consider the case of Craig Zucker, who in 2008 began selling New York City tap water under the name Tap'd NY, charging $1.50 for a 20 oz. bottle.[20] The steep price charged did not mean that the price of water had increased, since consumers didn't think tap (available for about a cent a glass) and Tap'd NY water were identical.

Furthermore, efforts by new and existing businesses to differentiate and improve their offerings and the eagerness of consumers to favor the new are routine. In some instances, new products offer measurable improvements (such as the clock speed of microprocessors), allowing price comparisons through so-called hedonic adjustments. But these are exceptions. Continuous, often nondestructive, and unmeasurable changes have become the rule, especially in services. Checking accounts now provide daily alerts and apps that allow us to deposit scanned images of checks. We can examine restaurant menus and book tables over

[20] See http://www.tapdny.com/ or http://articles.latimes.com/2009/feb/25/nation/na-tapwater25.

the smartphone and avoid lines at the airport by checking in at home. But such instances of getting more for our money do not and cannot be counted as price cuts or real increases in the output of services that now comprise two-thirds or more of economic activity.

Third, TFP estimates assume away the heterogeneity and dynamism that define the modern economy. Estimating the efficiency of converting inputs to outputs requires models to control for variations in the inputs, with the model of choice being the mathematically convenient Cobb-Douglas production function. But while convention and convenience favor this procedure, it is impossible to verify whether the Cobb-Douglas equation—or any other equation for that matter—properly represents how inputs are converted into outputs. Worse, the estimation procedures assume that all producers operate in perfectly competitive markets and that they convert inputs into unchanging outputs (save for measurable changes in quality) in a manner that conforms to a single formula. In other words, unvarying uniformity is assumed to deliver the innovation that TFP is claimed to measure.

Broad-based, unregimented innovation makes this virtually unthinkable. How plausible is it that Walmart's megaoutlets, Apple's retail stores (replete with Genius Bars), traditional supermarkets, and small grocery stores that use different processes to provide different shopping experiences can be modeled with the same Cobb-Douglas equation, even if they all fall under the rubric of retailing? Imagine using a single formula—say, for a cone—to estimate the ratio of surface area to volume for objects designed to have idiosyncratic and changing shapes. The assumption of perfect competition likewise challenges belief when large oligopolistic companies undertake about half of business investment and when even smaller companies strive to escape the profit-depressing forces of competition.

Jarring Disjunctions

It is conceivable that productivity measures may, in spite of the implausible assumptions, somehow track the overall changes in the efficiency of converting inputs to outputs. Perhaps uncounted consumer investment offsets the uncounted consumer surplus, or new uncounted inconveniences (for instance, less legroom on airplanes) offset new uncounted benefits (such as online check in); or the ratios of uncounted inputs to counted inputs and of the uncounted outputs to the counted outputs might never change;[21] or maybe models (with arbitrary, unverifiable structures) that assume identical production functions somehow correctly average out the great variety of ways in which different businesses convert inputs into outputs—and this average does not change over time. But the coincidences would have to be remarkable.

More likely, implausible assumptions produce palpably implausible results. Consider, as an important case in point, the supposed slump in productivity growth of information technology (IT)–using industries, claimed to be a major reason for the overall decline in productivity growth after 1972.

In 1987, Robert Solow famously wrote, "We see the computer age everywhere except in the productivity statistics."[22] By 1996, annual IT spending by U.S. firms had crossed the half-trillion-dollar level; yet in 1999, Robert Gordon—and in 2000, Jorgenson and Stiroh—suggested this was nearly for naught so far as productivity was concerned. Major IT-using sectors, wrote Jorgenson and Stiroh (2000, pp. 6–7), "continued to lag in productivity growth. Reconciliation of massive high-tech investment and relatively slow productivity growth in service industries remains an important task for proponents of the new economy position."[23]

But reconciling the Jorgenson and Stiroh result with the radical transformation of IT-using industries is even more challenging. By the year 2000, expanding big-box retailers, most notably Walmart, had wiped out tens of thousands of small merchants. Similarly, small regional banks had been merged into megasized national institutions such as Citicorp and Bank of America or had disappeared. With the new players came new ways of doing business: Walmart established global supply chains, for instance. The old players and ways of doing business didn't fall like trees stricken with Dutch elm disease. The

[21] Gordon (2014a) implicitly makes this assumption when he dismisses the undercounting of the consumer surplus. He writes that "real GDP measures have always missed vast amounts of consumer surplus since the dawn of the first industrial revolution almost three centuries ago" but provides no evidence for why this vast miss should be constant over time.

[22] Solow (1987).

[23] On the other side, Brynjolfsson (1993), Griliches (1994), and others suggested that the productivity paradox reflected deficiencies in measurements and methodological tool kits.

old order was forced out. How could this have happened unless the new order was in some way more productive than the old?

Or, could IT-using businesses simply have thrown away the greater part of half a trillion dollars in IT spending a year? Competition certainly can induce unprofitable investment: if one bank builds ATMs that customers value, others soon will as well, making everyone's investment unprofitable.[24] But this simply means that customers, not banks, derive most of the benefit from the technological "arms race." And, as mentioned, productivity estimates ignore consumer surplus derived from more convenient banking or more efficient global supply chains.

Putting aside the significant—and uncounted—consumer benefits, the plausibility of Jorgenson and Stiroh's finding is undermined by their assumption of perfectly competitive markets. This assumption is both completely unrealistic and virtually precludes the very phenomenon that their research purports to assess. Perfect competition may be a fair approximation for neighborhood florists or laundries. But the main IT-using and IT-producing industries are clearly oligopolistic. Moreover, if IT-using industries were in fact nearly perfectly competitive, how could IT-using businesses have had the capital needed to make large investments in IT? Similarly, if IT production was perfectly competitive, why or how could the producers have made the investments necessary to develop and market new IT products?

The acceleration of TFP in the Great Depression is even more surreal. The economy of the 1930s is said to have experienced "the most rapid TFP growth of any comparable period in American history."[25] Estimated TFP growth in the Depression decade was *50 percent higher* than the estimated TFP growth in the 1920s—a decade that with reason has been called roaring. Sprouting shantytowns and soup kitchens were emblematic of the sharp turn for the worse in the 1930s. With soaring unemployment sharply reducing the number of Americans who could contribute or benefit, it is hard to imagine how innovation could have been broad-based. If a scale shows that someone visibly wasting away has gained weight, we would think that the scale is defective, not that the person's bones became denser.

[24] As I argued in Bhidé (1986). Carr's 2004 book also makes this point.

[25] Shackleton (2013, p. 9).

But the acceleration of TFP while employment, consumption, and investment slumped does not faze those who don't question the assumptions underlying TFP's measurement.

Although TFP seems superior to piecemeal observation, it cannot reliably track widespread enterprise because it inappropriately ignores important differences. While little is lost in treating all births and deaths as identical occurrences in estimating trends in life expectancy, innovation entails an idiosyncratic quest for the new and different. Moreover, unlike births and deaths, innovative efforts and outcomes cannot be observed or unambiguously recorded. Nor can we rely on invariant, one-size-fits-all models to estimate the magnitudes; the course of human enterprise isn't like the motion of planets or gas molecules predestined by discoverable laws of nature. At best, we can examine multiple plausible correlates to form a judgment about the overall state of innovation. And returning to the present, although many signs reassure, data about the formation and growth of promising businesses is alarming, as we will now see.

Warranted Concerns

A simple taxonomy. To understand why businesses' debility matters, it is helpful to contrast promising new businesses with two other kinds of startups. One kind comprises new businesses backed by professional VCs that have been at the forefront of IT, biotech, and social-media development. Outsized returns earned by the winners in this category have helped attract more funds and attention, but the actual number of VC-backed startups is small. In the best of times, each year, fewer than a thousand new ventures receive seed or early-stage financing from venture capitalists; in lean times, only a few hundred receive such financing. In contrast, the total number of new businesses started in the United States every year ranges from about 500,000 to 2,000,000.[26]

A second kind comprises the numerous startups in mature, small-scale businesses such as beauty salons, auto-repair shops, and house-painting and house-cleaning services. Their contribution to

[26] The number of new businesses with employees started every year is, however, lower. In 2005, for instance, an estimated 653,100 "employer" firms were started in the United States (Source: Office of Advocacy of the U.S. Small Business Administration [2007, p. 5] from data provided by the U.S. Bureau of the Census, Statistics of U.S. Business).

the dynamism of the economy is limited. They start small and stay small, without hiring many employees or trying to change existing practices and industry structures. Their role is mainly to follow changes in the economy: as the auto industry struggles and fracking booms, beauty salons close in Michigan and open in North Dakota.

"Promising" startups have more potential than these popular mundane startups. They enter markets that offer greater opportunities for growth and profit, and their founders are better educated than the workforce at large. Successful ventures in this category can evolve into so-called gazelles, a few of which may then become multibillion-dollar public companies such as Microsoft and Dell. At the outset, however, the promise of promising businesses isn't enough to meet the exacting standards of professional VCs. They often target small niches, albeit in high-growth sectors. They don't have technologies or insights that could potentially create sustainable advantages, whereas many VC-backed businesses build on inventions or ideas previously developed in a lab or tinkerer's home. And founders of promising businesses usually lack the deep experience that VCs regard as necessary to manage rapid growth, although most do have college degrees. In lieu of venture capital, founders of promising businesses therefore "bootstrap" their ventures with personal funds or funds raised from relatives, friends, and individual investors.[27]

Narrowing innovation. While the funds raised and disbursed by VCs remains high, more capital has not materially increased the proportion of startups funded with professional venture capital.[28] As VCs raise more capital, they tend to pay higher prices for "good" deals rather than lower eligibility standards to fund more startups. At the same time, recent papers—for instance, by Hathaway and Litan (2014a, 2014b) and especially by Haltiwanger (for example, Haltiwanger et al. [2014])—suggest that promising startups may have become a beleaguered species. For instance, Decker, Haltiwanger, Jarmin, and Miranda (2014) report a marked decline in the rate at which new businesses have been started in the United States in recent decades. And this decline seems especially pronounced in

[27] Chapters 1 through 6 of Bhidé (2000) provide a detailed comparative analysis of the three types of startups.

[28] Gompers and Lerner (1998) estimate that a doubling of capital available to venture funds leads to a 7 to 21 percent increase in the prices they pay for their stakes.

startups that then grow rapidly and in the industry sectors where promising businesses have previously flourished.

Some researchers attribute to VC-backed businesses an exceptional capacity for efficient innovation,[29] so small increases in their numbers might compensate for fewer promising startups. I am, however, skeptical of the research results. Returns on VC investment do not corroborate claims of exceptional innovation efficiency: while some VCs have earned consistently high returns, the average for the industry has been unremarkable. More importantly, comparisons of innovation efficiency are unreliable because, like macroestimates of productivity, they rely on one-size-fits-all measures of outputs (such as patent counts) and models to control for variations in inputs. In reality, at least as from my bottom-up view, different organizations use different inputs and processes to produce different (and often complementary) innovations. There are good and bad trumpet players and flautists, but to say that trumpet players as a class are more productive because they blow more wind through their instruments misses the point. Just as symphonies require many instruments—replacing flautists with trumpeters doesn't necessarily improve a performance—VC-backed businesses, which clearly have an edge in securing and exploiting patents, cannot substitute for the innovative contributions of promising startups.

Promising startups have an advantage over VC-backed startups (and large companies) in pursuing small, highly uncertain opportunities. VCs have a strong preference for ventures where there is an objective basis for expecting large payoffs quickly, typically five to seven years.[30] In contrast, self-financed entrepreneurs are more

[29] The best-known example is a paper by Kortum and Lerner (2000). Using a variety of methods but then "focusing on a conservative middle ground," they estimate that "a dollar of venture capital appears to be three times more potent in stimulating patenting than a dollar of traditional corporate R&D." They then suggest that "venture capital, even though it averaged less than 3 percent of corporate R&D from 1983 to 1992, is responsible for a much greater share—about 8 percent—of U.S. industrial innovations during this decade."

[30] I provided a detailed "Knightian" explanation for the nature and underpinnings of VC investment criteria in Bhidé (2000) and Bhidé (2006). Mainstream finance theories ignore Knightian uncertainty and focus on information asymmetries—the so-called lemon problem—that my fieldwork suggests are of less concern to real-world investors and entrepreneurs than the contracting problems that arise because of Knightian uncertainty.

willing to act on hunches (or difficult-to-communicate personal experience) and pursue opportunities where there is no clear prospect for large payoffs. Low-cost ventures started by such entrepreneurs can help products and technologies that have no compelling use at the outset find a foothold. For instance, a self-financed entrepreneur, Ed Roberts, introduced the Altair, the first personal computer, in 1975, and Paul Allen and Bill Gates—also self-financed—soon developed its early software. Later, when technological and market uncertainties had been reduced, VCs such as Arthur Rock and large companies such as IBM financed or undertook initiatives that helped create a huge market.

An even-larger number of promising startups facilitate the diffusion of new technologies after they have gained traction by providing goods and services whose revenue potential is too small or uncertain to interest VCs or large companies. After IBM's entry in 1981 legitimized personal computers as a mainstream product, a swarm of self-financed startups provided installation and maintenance services, "add-on" hardware and software, and educational books and videos that both took advantage of and helped advance burgeoning PC sales. A similar pattern is now being repeated with tablets and mobile phones. Self-financed entrepreneurs have capitalized on and increased the popularity of mobile devices by producing hundreds of thousands of apps and peripherals such as cases and screen protectors. The revenues and profits realized by most entrepreneurs are small, but the availability of a wide selection of complements promotes the increasing use of mobile devices.

More modest prospects and paltry resources also encourage promising businesses to harness the contributions of individuals that VC-backed businesses and large companies tend to avoid. VC-backed businesses favor proven expertise because they have to show quick results before the money runs out.[31] And because of the

[31] "Even though we are located in Austin, we haven't hired a lot of University of Texas graduates," the founder of one high-tech company told me. "In fact, we rarely hire people directly out of any college. We have a saying around here: 'There are only so many people we can have on our staff with learner's permits.'" Similarly, the CEO of a biotech startup observed, "When you develop a pharmaceutical product, you can't make it up as you go along. You have to know what the next step is. You can't conduct a clinical trial unless you have people who have conducted clinical trials before."

glamor and upside of their stock options, VC-backed startups can attract hot shots and rising stars without having to pay high salaries.

Large companies can afford to train entry-level employees who don't have job-specific skills. Unfortunately, such employers can also be picky, hiring individuals with good educational qualifications and famously, in cases such as Google and Microsoft, individuals with exceptional intelligence and talent. Inflexible human resources policies and concerns about legal liability preclude hiring the hard cases, such as high-school dropouts, individuals with spotty job histories, or ex-felons, the latter of whom now comprise about one-eighth of the U.S. male working-age population.[32]

Concerns about overqualification can work against applicants seeking positions they are more than qualified to fill in established or VC-backed companies: employers worry that a desperate individual who takes an unsatisfactory job now will always be looking for a better opportunity. Employers also worry that there is a reason why an applicant might be unemployed; it's safer to fill a position by poaching an already-employed individual even if it means paying a premium wage.

In contrast, promising businesses provide a natural home for those with limited skills or derailed careers. "We were careful to make sure that we only employed people who were unemployed," one founder I interviewed said. "We were cheap. And if we went under and it didn't work out for them, we wouldn't feel so bad." Another recalled how his "scruffy business" couldn't have functioned without "burly, tattooed illegals and felons."[33]

Arguably, the thinning ranks of promising ventures helped maintain chronic joblessness (unemployment for six months or longer) at near-record levels in 2014, whereas short-term unemployment and postings of job vacancies recovered to about what was considered "normal" before the 2008 crisis.

[32] See Schmitt and Warner (2010). Meanwhile, nearly one-third of adult Americans have an arrest or conviction record. Emshwiller and Fields (2014, p. A4).

[33] Every hard case that gets a job doesn't get to keep it, of course. "We had to fire many employees," one entrepreneur told me, "because to get hired was a joke. If you came in and we needed a warm body, you were hired. Literally for any position." But improvised startups do give a chance to people whom large companies or glamorous startups wouldn't touch.

Keeping It Broad

According to Schumpeter, economically significant innovations are "large" and "spontaneous" rather than "small" and "adaptive." They so displace the "equilibrium point" that "the new one cannot be reached from the old one by infinitesimal steps. Add as many mail coaches as you please, you will never get a railway thereby." And, according to Schumpeter, only exceptional individuals undertake such innovations. "To act with confidence beyond the range of familiar beacons," wrote Schumpeter, "requires aptitudes that are present only in a small fraction of the population."[34]

Like Schumpeter's sweeping rhetoric about creative destruction being "the essential fact about capitalism," this characterization of innovation and innovators is at best partially true. As Nathan Rosenberg (1976) and other economic historians have documented (and my own field-based research corroborates[35]), revolutionary technological change, like the evolution of humans from primordial microorganisms, is the accretive result of innumerable small changes. And while even small changes require acting beyond the range of familiar beacons, such an aptitude is widely distributed in the population.

Harnessing the aptitudes of the many to make change routine and ubiquitous has been a signal achievement. As Phelps's *Mass Flourishing* and his prior writings emphasize, the measure of a good economy lies in the satisfaction it provides to the many, not in the success of a few.[36] And these satisfactions go beyond material rewards: they include, for instance, the exhilaration of overcoming challenges. Indeed, they go hand in hand: a good economy cannot provide widespread material prosperity without harnessing the creativity and enterprise of the many. All must have the opportunity to innovate, to try out new things: not just scientists and engineers but also graphic artists, shop-floor workers, salespersons, and advertising agencies; not just the developers of new products but their venturesome consumers.

But as less glamorous ventures struggle while VCs race to fund elite entrepreneurs, opportunities to contribute to and benefit from a

[34] Schumpeter (1942, p. 132).

[35] Chapter 13 of Bhidé (2000) discusses Rosenberg's 1976 critique of Schumpeter's theories and my extensions to this critique.

[36] Phelps (2013).

dynamic economy may be narrowing. Worse yet, we don't know why unglamorous entrepreneurship has been in steady decline. Opinions range from growing health care costs to excessive regulation. My own analysis (Bhidé 2010) suggests that diversion of credit—and more importantly of specialized lending capacity—from small-business loans to consumer and mortgage loans has played a significant role. In truth, however, reformers, politicians, and academics know little of how a netherworld they rarely encounter works. The beleaguered state of less visible entrepreneurs is a mystery that badly needs investigation.

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9. Is Entrepreneurship in Decline?

Alex Tabarrok and Nathan Goldschlag[1]

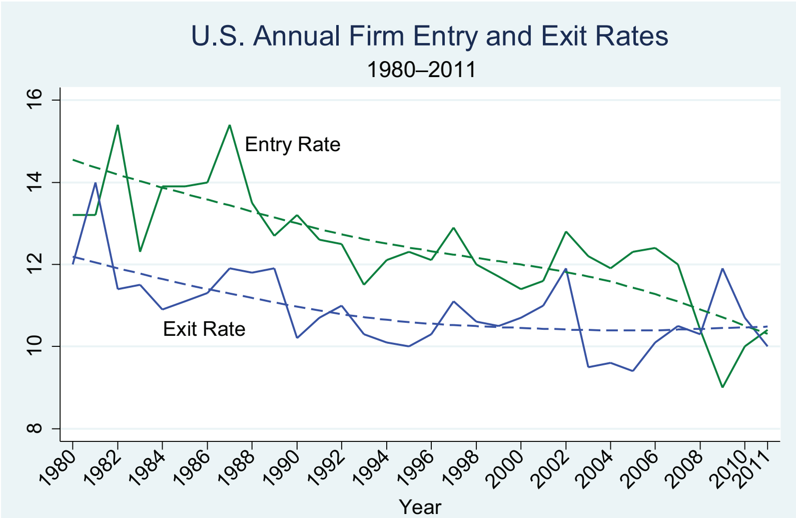
The U.S. economy has been one of the most dynamic economies in the world, but recent research suggests that U.S. dynamism is in decline. Well, what is dynamism? We may be tempted to say that we know it when we see it, and, in the past, discussions of dynamism were invariably impressionistic. Pointing to Steve Jobs, Elon Musk, or the upending of the taxi industry by Uber, however, isn't enough to say whether dynamism has increased or decreased or is higher or lower in the United States than, say, France. What makes the recent discussion different is that new, comprehensive data sets put together by the U.S. Census Bureau and statistical agencies abroad have given us quantitative measures of dynamism that are signaling a potential problem. Although quantitative data are of enormous help, however, data are always subject to interpretation and questions remain as to the relationship between dynamism and entrepreneurship, flexibility, and growth.

The evidence on the decline of dynamism comes from microdata on business startups and job creation (Decker et al. 2014). Between 1980 and 2011, for example, the annual entry rate of new firms (measured by the number of new firms created in a year divided by the total number of firms) fell from about 15 percent annually to 10 percent annually, as shown in Figure 9.1. The exit rate, however, fell by much less.

Although most new firms fail, a large proportion of net job creation is created by the minority of new firms that succeed and grow (Decker et al. 2014). It's not surprising, therefore, that, as shown in Figure 9.2, annual U.S. job creation has also declined while job destruction has declined by much less.

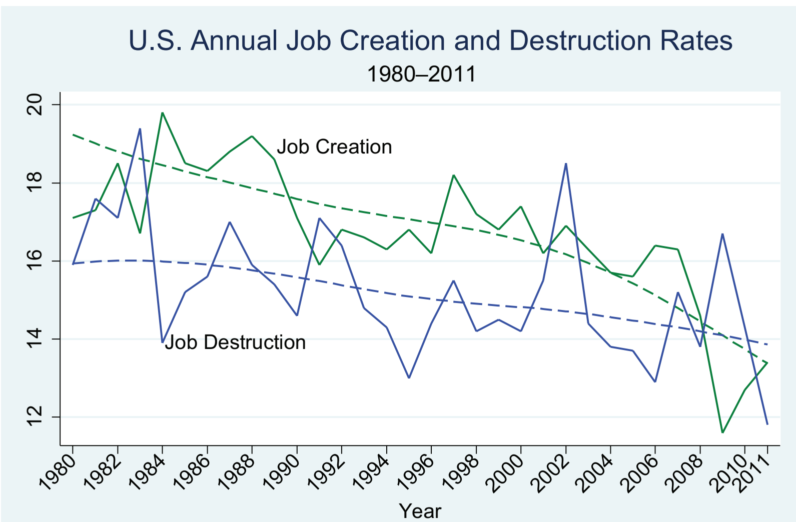
[1] Alex Tabarrok is a professor of economics at George Mason University, and Nathan Goldschlag is an economist with the Center for Economic Studies, U.S. Census Bureau.

Figure 9.1



Source: U.S. Census Business Dynamics Statistics and Decker et al. 2014.
Note: Dotted lines are HP smoothed filter with multiplier 400.

Figure 9.2

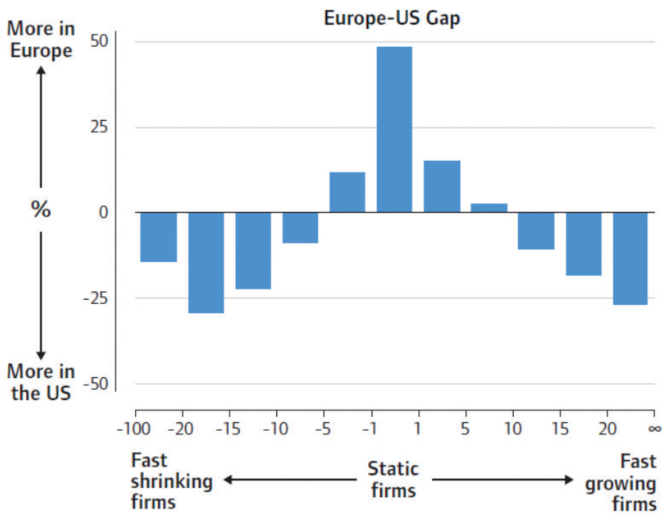


Source: U.S. Census Business Dynamics Statistics and Decker et al. 2014.
Note: Dotted lines are HP smoothed filter with multiplier 400.

Other sources compare business dynamism across countries (Bravo-Biosca 2010, Criscuolo, Gal, and Menon 2014). Compared to Europe, for example, the United States has traditionally been more dynamic. In particular, successful firms in the United States grow more quickly than in Europe, and unsuccessful firms die more quickly in the United States than in Europe. Figure 9.3 shows the distribution of growth rates of firms in Europe relative to firms in the United States. In the middle of the distribution are firms that are static—both the behemoths and the small family firms that have been doing the same thing for generations. In the static category, Europe dominates. At the ends of the distribution are the fast firms, fast-dying firms on the left and the fast-growing firms on the right. In both of these cases, the United States dominates. It may be that the United States is becoming more like Europe.

A closely related point concerns the age distribution of firms. In all economies, young firms tend to be small, but small firms are not necessarily young. The United States has historically had a relatively high share of small firms that are young and also a relatively high share of large firms that are young. The latter,

Figure 9.3
Distribution of Firm Growth Rates in the United States and Europe



Source: Bravo-Biosca (2010).

of course, are relatively rare, but it's in the United States that a small firm has the greatest probability of growing rapidly and thus becoming large. Conditional on survival, it is these young firms that account for a significant share of net job growth (Decker et al. 2014; Criscuolo, Gal, and Menon 2014). Overall, however, U.S. firms are getting older. The share of firms aged 16 years or more, for example, rose from 23 percent in 1992 to 34 percent in 2011 (Hathaway and Litan 2014). Since older firms tend to be larger and larger firms tend to be older, the share of employment in older firms has increased from 60 percent in 1992 to 72 percent in 2011, as shown in Figure 9.4.

Is It Regulation?

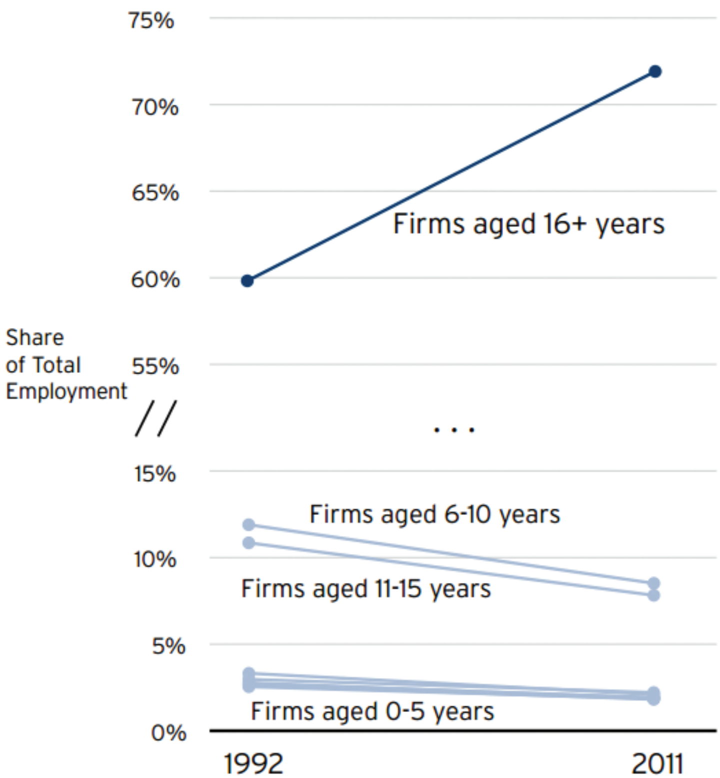
One potential explanation for the secular decline in firm dynamism is regulations that impede entry, exit, expansion, and contraction. Regulation has increased in the United States over time, but it has not increased at the same rate in all industries. Thus, one test of whether increased regulation is the cause of decreased dynamism is to examine whether dynamism by industry is correlated with regulation by industry.

In preliminary work, Goldschlag and Tabarrok (2014) combine measures of industry dynamism from the Census Bureau's Statistics of U.S. Businesses with measures of industry regulation from RegData, a new data set on regulatory stringency by industry produced by Al-Ubaydli and McLaughlin (2014). They then test whether increased regulation can explain reduced dynamism. Surprisingly, the answer appears to be no.

Regulatory stringency does vary greatly by industry. More than 50 percent of industries, for example, received fewer than 354 regulatory restrictions between 1998 and 2012, while the top 5 percent of industries were subjected to more than 16,000 restrictions. (See Al-Ubaydli and McLaughlin 2014 and Goldschlag and Tabarrok 2014 for more detail on the measure of regulatory restrictions.)

How do measures of dynamism correlate with regulatory restrictions? Figure 9.5 shows job-creation rates against regulatory stringency (both averaged over 1999–2011) by industry (measured at the three-digit NAICS level). The correlation between job-creation rates and restrictions is weak and positive. Note that restrictions are plotted on a log scale since they vary from a few hundred in furniture

Figure 9.4
DISTRIBUTION OF TOTAL EMPLOYMENT BY FIRM AGE, 1992 VERSUS 2011



SOURCE: Hathaway and Litan (2014).

production to over 100,000 restrictions in the air-transport industry. Despite significant variation in regulation, there is only a small change in job-creation rates, and it is positive, not negative—that is, industries with greater regulation had slightly higher job-creation rates.

The story for startup rates is similar. As shown in Figure 9.6, regulation is weakly positively correlated with startup rates.

These simple scatter plots do not control for other factors—in particular, industry effects. It could be the case that industries with a lot

Figure 9.5

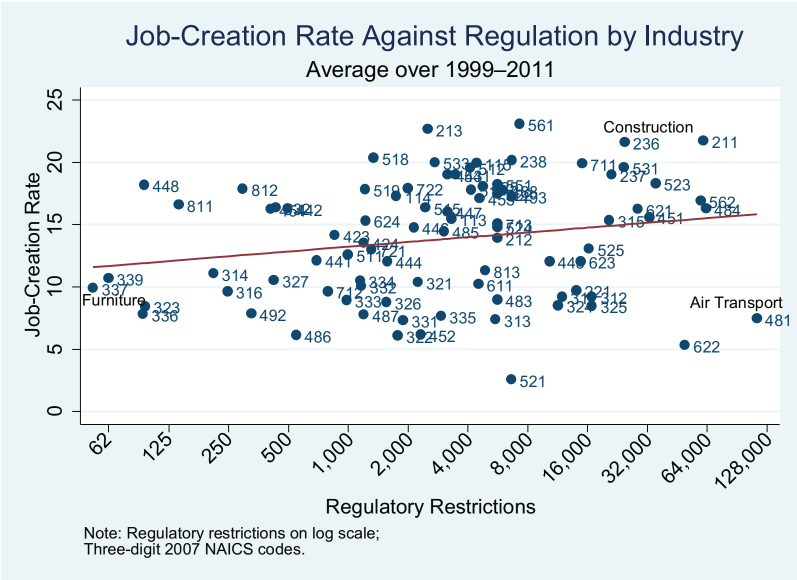
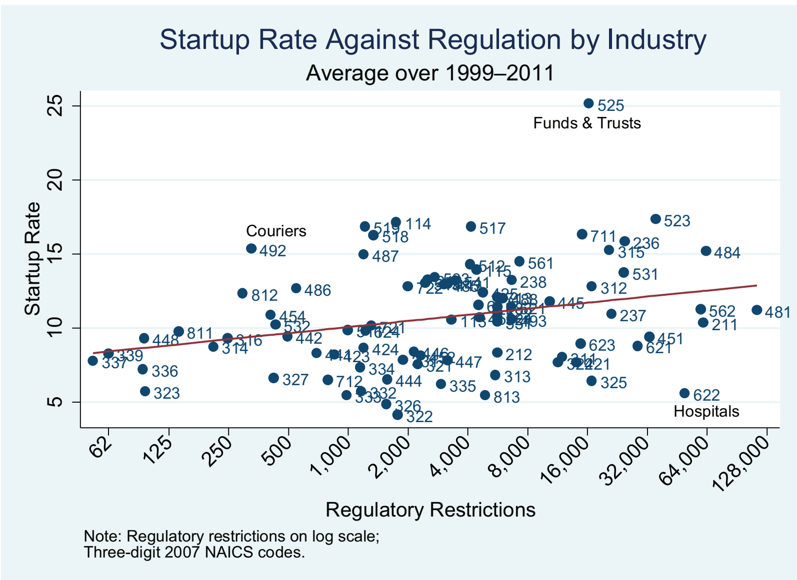


Figure 9.6



of job creation and startups attract more regulation than other industries and as a result of this reverse causation we find a positive correlation between dynamism and regulation. Thus, Goldschlag and Tabarrok (2014) look in more detail at within-industry effects. Do industries that are regulated more over time show lower dynamism rates? Although this does happen in some industries, the effect of regulation on dynamism continues to be small in more sophisticated analyses.

Thus, perhaps surprisingly, regulation does not appear to be the cause of decreased dynamism. A few other patterns in the data suggest that regulation may not be to blame for the decline in dynamism. First, as we discuss in greater length below, when looking across countries, the dominant type of regulatory restriction (or other friction) is one that prevents firms from growing large. U.S. firms, however, are the largest in the world and growing larger. Moreover, on average, larger firms are more productive and in the United States this correlation between size and productivity is higher than anywhere else in the world (Haltiwanger 2012). Thus, unlike in most of the world, size per se doesn't appear to be penalized in the United States.

Regulation, however, could certainly deter startups or impede small firms from growing into large firms. As already noted, preliminary results do not find a relationship between regulation and startups in the data. Moreover, if small firms were being penalized, then theory suggests that when entry does occur it would be by larger firms. We do see some weak evidence for this across countries. The average entry size for a manufacturing startup in France, for example, is more than twice as large as in the United States. In the United States, however, there is no trend toward increasing entry size (Haltiwanger, Jarmin, and Miranda 2013), which is what we would expect if regulation was increasing the cost of small firms disproportionately.

Finally, startup growth is also declining in other countries (Criscuolo, Gal, and Menon 2014), and dynamism is declining across most sectors of the U.S. economy and also across most U.S. states (Decker et al. 2014). Since regulation varies widely across industries, countries, states, and time, the consistent decline of dynamism across these categories suggests that regulation is not the cause.

If regulation is not the cause of declining dynamism, then there are two possible stories—one pessimistic, the other optimistic. If regulation was the cause of declining dynamism, then we would at least know how to solve the problem (it might be politically difficult to solve the problem, but we would at least know what to do in principle). If regulation isn't the cause, then we have very little idea what to do. Suppose the cause is a declining spirit of entrepreneurship. If so, we have no real knowledge about how to rekindle that spirit. Or perhaps, as we discuss below, the cause is that there is less to be entrepreneurial about—a great stagnation. Once again, we don't have a surefire solution.

The optimistic story is that if regulation isn't the cause of declining dynamism, then maybe declining dynamism isn't such a bad thing. We should not let words guide our normative evaluation; dynamism sounds like a good thing and decline like a bad thing, but if we substituted churn for dynamism we might say there has been a decline in churn. Or, better yet, we might say that there has been an increase in business stability. We turn to exploring these two stories in greater depth.

A Pessimistic Story about Causality

First, a caution on causality. Productivity growth has declined as business dynamism has declined. It's even true that some productivity growth is caused by business dynamism. Even so, it doesn't necessarily follow that the decline in productivity growth is due to the decline in business dynamism. The causality, for example, could be the other way—from a decline in productivity growth to a decline in business dynamism. One reason that entrepreneurs start new firms is precisely that they believe that new ideas and technological developments can be used profitably in new business ventures. If productivity growth has declined for primarily exogenous reasons (as argued, for example, by Cowen 2011 and Gordon 2012), then we may expect fewer new-business startups as a result. The direction of causality is important, as the policy levers that we do have may vary in effectiveness depending on the cause. If business dynamism is primary, for example, then we may look for direct levers such as regulation of new businesses (contrary to our preliminary results) or an increase in entrepreneurial immigration. If deeper technological change is at work, then our options are more limited, but perhaps policy could be more focused on improving science and math education, investing in knowledge production, and fostering creativity.

Alternative Perspectives

The standard explanation of the above facts is that entrepreneurship is in decline, with negative consequences for efficiency and growth. We propose several other interpretations with less dire conclusions. We do not dispute that the standard interpretation *may* be correct. Our proposals should be taken as hypotheses.

Firm Size and Entrepreneurship

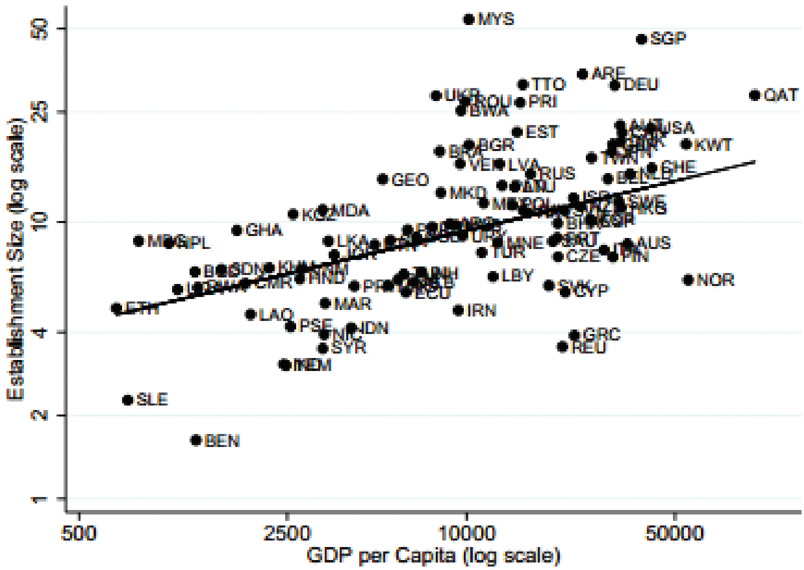
The literature takes for granted that entrepreneurship is about the growth of young, small firms. The identification is problematic for three reasons. First, when looking across countries, it's larger firms that are associated with more advanced development. Second, entrepreneurship occurs within firms—even large firms—as well as between firms. Third, there is a great deal of excess reallocation and churn, and declines in these magnitudes represent gains, not declines. We examine each of these in turn.

The most-developed economies have the largest firms. The least-developed economies have the most entrepreneurs. One might imagine that the least-developed economies are dominated by inefficient, lumbering behemoths while the more developed economies are characterized by smaller, nimble entrepreneurial firms. In the case of the communist economies, that characterization had some element of truth. Nevertheless, today and on average, firm size increases with gross domestic product per capita as illustrated in Figure 9.7. In the poorest 10 percent of countries, average firm size is 6 persons, while in the richest 10 percent it's more than three times larger—19 persons (Bento and Restuccia 2014).[2]

The second fact, that the least-developed economies have the most entrepreneurs, is closely related to the first. If we define entrepreneurship as self-employment, then there is much more entrepreneurship in poorer countries. People in poorer countries have to be entrepreneurs because there are relatively few

[2] Technically, Bento and Restuccia measure establishment size, which is the number of workers at a particular location. Firm size will be somewhat larger but more so in more developed economies, so this comparison somewhat understates the difference.

Figure 9.7
Establishment Size per Capita



Source: Bento and Restuccia (2014).
Note: Countries with fewer than 500,000 people omitted.

jobs—that is to say, few employers of large numbers of workers. Moreover, although not all self-employed workers have the skills or temperament for entrepreneurship, the identification of entrepreneurship with self-employment is not a definitional sleight-of-hand. Travelers to less developed economies often are surprised at how much more market-oriented, dynamic, and entrepreneurial these economies appear to the naked eye. Indeed, tourists are more likely to visit an actual market in a developing economy than they are at home. The hustle and bustle of the town market provide a display of real entrepreneurship. The greater familiarity that people in less developed countries have with entrepreneurship is likely one reason why immigrants to the United States are more than twice as likely to start new firms as are natives (Fairlie 2013).

The problem with less developed countries is not that they lack entrepreneurs but that entrepreneurs cannot grow their firms large enough to become major employers.[3] The distribution of firm size is highly right skewed, so the share of workers employed in large firms increases even more dramatically with development than does average firm size. In Ethiopia, Egypt, and India, for example, more than half of all workers are employed in firms that employ fewer than 10 employees. In the United States, in contrast, more than half of all workers work for firms that employ more than 250 people, even though these firms account for less than one percent of all firms (Criscuolo, Gal, and Menon 2014). Fortunately, larger firms are better managed, more productive, and more innovative than are smaller firms, and they pay higher wages as well (World Bank 2013). Indeed, the best-managed firms in the world are the large multinationals (Bloom and Van Reenen 2010).

Why are these cross-country findings important for understanding the development of business dynamism in the United States? The cross-country effects are also found across time: namely, as economies develop—in particular, as the U.S. economy has developed—we have seen larger firms, a larger share of employment in large firms, and *less* apparent entrepreneurship (Poschke 2014). The fact that these correlations are seen widely in both cross-sectional and time-series data suggests that they have some causal basis (see Lucas 1978 and Poschke 2014 for models of the possible causality).

In short, some of the measures of declining business dynamism that on the surface appear unambiguously negative are in fact associated with greater gross domestic product per capita. Thus, we should be cautious about drawing normative conclusions from the fact of declining business dynamism.

Entrepreneurship in Large Firms

The annals of entrepreneurship are replete with David-versus-Goliath stories, but entrepreneurship is not limited to startups. In 2006, when Alan Mulally became chief executive of Ford Motor Company, Ford was losing billions, product quality was declining,

[3] In the United States, for example, firms are much more likely to increase in size as they age than firms in other economies, especially relative to developing economies. By age 35, for example, the typical firm in the United States has grown by over 700 percent, in Mexico a comparable firm by only 100 percent, and in India by just 40 percent (Hsieh and Klenow 2009).

inefficiencies were tremendous, union contracts were rigid, and Ford's credit rating had been downgraded to junk—and that was in a growing economy. When the financial crisis hit in 2008–9, Ford's seemingly stronger competitors General Motors and Chrysler filed for bankruptcy and were kept afloat only through a government bailout. In one of the great turnarounds in business history, however, Mulally guided Ford through the crisis without bankruptcy or a bailout and returned the firm to profitability by 2010, with record profits by 2014 (Hoffman 2013, Woodall 2014).

Mulally's turnaround of Ford illustrates two propositions. First, entrepreneurship is not limited to small firms. Indeed, because of scale, entrepreneurship at large firms is much more important than at small firms. Moreover, there is some evidence that chief executive officers (CEOs) have become less managerial and more entrepreneurial over time. CEO turnover, for example, has increased over time and the turnover–performance gradient has grown steeper—that is, CEOs whose firms perform poorly are increasingly likely to be fired (Murphy and Zabojnik 2007, Kaplan and Minton 2006). CEOs are also less likely to be insiders than in the past. In the 1970s, only 15 percent of the CEOs in S&P 500 firms were outside appointments; by 2000–2005 the figure had risen to 32.7 percent (Murphy and Zabojnik 2007). The decrease in the appointment of insiders and increase in the appointment of outsiders suggest that firm-specific knowledge and skills—"How does this firm work? What do we do? What relationships need to be managed?"—became less important and more general managerial or entrepreneurial ability became more important in managing U.S. corporations.

Alan Mulally's career is a case in point. He came to Ford from Boeing, where he had been president of Boeing Commercial Airplanes and was credited with a successful competition against Airbus. After retiring from Ford in 2014, he was appointed to Google's board of directors—further illustrating the importance of general entrepreneurial ability rather than firm-specific knowledge.

Second, by all accounts, Mulally remade Ford into a different firm—not just a different set of products (although there were innovative new designs and building methods) but also a new corporate culture (Hoffman 2013).

What then is a startup? We measure startups as firms that yesterday had zero workers and today have one or more workers.

We say startups are born. The metaphor may constrain. Philosophers wrestle with the problem of identity even for persons (Parfit 1986). The problem is more severe for objects and organizations. The Ise Grand Shrine, Japan's most sacred shrine, was first built around AD 686. Every 20 years since that time, the entire shrine complex, some 62 buildings, has been dismantled and removed and an entirely new structure rebuilt in exactly the same place in exactly the same way with exactly the same 16,000 artifacts put back in place. This has been going on for over 1,000 years. Is the Ise Grand Shrine an old building or a new one?

The problem is not merely philosophical. We measure new firms as firms that go from zero to one or more employees, but restructuring and remaking old firms is not counted. If Ford can be said to have been reborn in the ashes of the financial crisis, then innovation, entrepreneurship, and reallocation may be larger than we measure.

Can this perspective be reconciled with the time trends? It's plausible that information technology has made older and larger firms more flexible, nimble, and capable of change. Consider Zara, the world's largest fashion retailer, founded by Amancio Ortega, the third- or fourth-richest person in the world, depending on the day one counts. In the past, a fashion retailer would have one line per season planned well in advance and based mostly on trends and guesswork about consumer demand. In contrast, twice a week, the managers of each of Zara's 6,500 stores examine sales data and also feedback from shoppers and then order product from headquarters. At the Spanish headquarters, trends are identified and designers are charged with creating new product. Within weeks, Zara stores have new product on the shelves. In this way Zara is able to offer five or six new lines over the course of a season (Ruddick 2014).

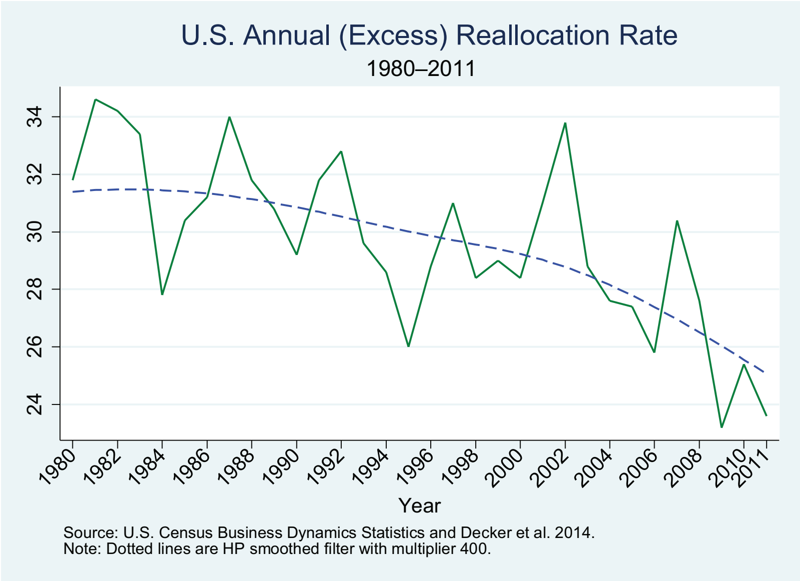
In the past, a fashion retailer that did a poor job of predicting fashion trends for one or two seasons might have found itself vulnerable to an upstart startup. Today, the same fashion retailer can turn on a dime and correct its fashion faux pas before a startup has a chance to grab market share. Business dynamism as measured by entry and reallocation will decline, but measured by the *goals* of business dynamism, the movement of resources to their highest-valued uses, and the satisfaction of consumer demand, the decline has been an improvement.

Excess Reallocation and Churn

By focusing on the goals of business dynamism, it becomes clear that startups are not necessarily a sign of vigor, growth, and efficiency but instead can signal inefficiency. Why should firms have to die for the economy to grow? Death and birth are painful processes. Bankruptcy wastes resources, reallocation takes time, and most startups fail. High job-creation and job-destruction rates speak to dynamism but also to churn. Reallocation rates are down in the economy, but so are excess reallocation rates, the rate of reallocation above that necessary for net job creation, and that can be a positive development (see Figure 9.8).

Walmart, the world's largest firm by employment, has revolutionized the retail sector while driving out many so-called mom-and-pop stores in the process. The Walmart vs. mom-and-pop story that's commonly told paints a picture of a bucolic time in which family-run firms that had been around for generations are driven out in a giant mass-extinction event by the arrival of asteroid Walmart. The truth, however, is that, like other small firms, the moms and pops

Figure 9.8



rarely lasted for very long. Mom and Pop churned, with Mom and Pop Jones being replaced by Mom and Pop Smith and then Mom and Pop Garcia on a recurring basis (Haltiwanger 2012). Walmart and other big-box retailers greatly increased productivity in the retail sector—Walmart alone was responsible for a measurable share of U.S. productivity growth in the mid-1990s—and, in addition, the big-box retailers have been more stable. As a result, dynamism, as measured by reallocation, has declined, but the efficiency by which consumer demand is satisfied has greatly improved.

Death and birth are redeemed if they are necessary to improve productivity and innovation, but it would be preferable if older and larger firms could instead become more flexible, nimble, and capable of change. Information technology may have made that the case, allowing firms to be reborn from within rather than dying and being replaced by new firms.

National and International Entrepreneurship

The U.S. economy is very large and therefore largely internally driven. Nevertheless, imports of goods and services have risen from approximately 5 percent of gross domestic product in 1970 to around 17 percent today. The more internationalized the economy, the less national statistics on business dynamism may reflect reality. In 2013, Apple Inc. had 748 suppliers, only 81 of which were in the United States while over 600 were located in Asia (Barreda 2013). Most importantly, Apple is an exacting customer that can and does hire and fire suppliers on the basis of slim differences in price and quality (Satariano and Burrows 2014). Firms live and die in anticipation and fear of a call from Cupertino. Like the Ise Grand Shrine, Apple continues even as its component parts are dismantled and rebuilt with every iPhone iteration. The underlying flux in suppliers, however, is invisible to the customer as well as U.S. business-dynamics statistics.

Entrepreneurship, Globalization, and the Future

William Gibson famously said that “the future is already here—it’s just not very evenly distributed.” That, however, was in 1992. Today, the future is much more evenly distributed. Consider mobile phones. Almost five billion people today have a mobile phone and nearly two billion people have a smartphone. Today’s smartphone is more powerful than a Cray supercomputer was when Gibson spoke, and when

Gibson spoke there were just a few hundred Crays in the world. Two billion Crays is a lot more evenly distributed. Not only does today's smartphone have more memory and processing power than the supercomputers of the past, it's also much more connected to the world with cameras, microphones, gyroscopic orientation, GPS receivers, Wi-Fi, cellular, Bluetooth connectivity, and much more. Thus, nearly two billion people are equipped today with a supercomputer networked to the world around it and to other supercomputers. The ability of small entrepreneurs from virtually anywhere in the world to tie into this network of vast computational power must alone be a tremendous boost for entrepreneurship.

As late as 1990, just seven nations accounted for 92 percent of world research and development (R&D).[4] Today those nations are spending more than ever before on R&D, but now they account for only 56 percent of the total (Organization for Economic Cooperation and Development 2014). World R&D is increasing rapidly for multiple reasons. First, the capacity for research and development has increased—not just in the spread of supercomputer-like power but also in the spread of human capital. The number of world scientists and engineers is increasing rapidly as China and India increase the percentage of their population that is highly educated. Second, the demand for R&D is increasing as world wealth increases. Greater wealth means a deeper market, which increases the incentives to invest in R&D. If China and India were as wealthy as the United States is today, the market for cancer drugs would be eight times larger than it is now. This illustrates why we all have an interest in other countries becoming rich (Tabarrok 2011).

When we speak of globalization, we often speak of exports and imports, of goods crossing borders. But in the information age, globalization also means an erasing of borders. Skype was created by Estonian programmers and launched simultaneously everywhere in the world in 2003. What kind of startup is Skype? Is Skype an Estonian startup or a world startup? Today, especially in information technology, but increasingly in other areas of technology as well, the physical location of an entrepreneur doesn't tell us much about the

[4] UNESCO, *UNESCO Science Report 2010*, http://www.unesco.org/new/en/natural-sciences/science-technology/prospective-studies/unesco-science-report/unesco-science-report-2010/.

location of innovation or value. Chinese and Indian entrepreneurs, just like Estonian entrepreneurs, can also be U.S. entrepreneurs. Thus, we remain optimistic about the global state of entrepreneurship.

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