Policy Analysis

No. 737 October 8, 2013

Why Growth Is Getting Harder

by Brink Lindsey

Executive Summary

For over a century, the trend line for the long-term growth of the U.S. economy has held remarkably steady. Notwithstanding huge changes over time in economic, social, and political conditions, growth in real gross domestic product (GDP) per capita has fluctuated fairly closely around an average annual rate of approximately 2 percent. Looking ahead, however, there are strong reasons for doubting that this historic norm can be maintained.

Consider the four constituent elements of economic growth tracked by conventional growth accounting: (1) growth in labor participation, or annual hours worked per capita; (2) growth in labor quality, or the skill level of the workforce; (3) growth in capital deepening, or the amount of physical capital invested per worker; and (4) growth in so-called total factor productivity, or output per unit of quality-adjusted labor and capital. Over the course of the 20th century, these various components fluctuated in their contributions to overall growth. The fluctuations, however, tended to offset each other, so that weakness in one element was compensated for by strength in another. In the 21st century, this pattern of offsetting fluctuations has come to a halt as all growth components have fallen off simultaneously.

The simultaneous weakening of all the components of economic growth does not mean that slow growth is inevitable from here on out. The trends for one or more of them could reverse direction tomorrow. Nevertheless, it is difficult to resist the conclusion that the conditions for growth are less favorable than they used to be. In other words, growth is getting harder. Consequently, policies that are more friendly to long-term growth will be needed if more robust growth is to be revived.

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The sluggish performance of the economy since the Great Recession is likely to persist in the coming years.

Introduction

The great macroeconomic disturbances of the 20th century gave rise to gloomy predictions that the bad times were here to stay. During the Great Depression, Keynesian "secular stagnationists" claimed that slowing population growth and the maturation of the industrial economy meant that the private sector was no longer capable of generating robust growth. Future prosperity, in their view, would require increasingly massive government spending. And during the stagflation of the 1970s, there was widespread hand wringing about "limits to growth." Heightened awareness of environmental degradation, combined with a sharp spike in oil prices, led many people to believe that tightening resource constraints would make the growth rates of the past unsustainable.

Now, in the first great macroeconomic disturbance of the 21st century, talk of a prolonged slump is once again in the air. In his provocative 2011 book *The Great Stagnation*, economist Tyler Cowen argues that the "low-hanging fruit" of easy growth has already been consumed and that the slowdown in productivity growth and median income gains over the past few decades is the "new normal."[1] Meanwhile, a much-discussed 2012 paper by economist Robert Gordon speculates that the 250-year era of modern economic growth may now be coming to an end.[2] In reaching their pessimistic conclusions, both Cowen and Gordon lean heavily on the controversial contention that we are quite simply running out of big new ideas for improving consumer welfare.

Looking back at the 1930s and 1970s, we can now see that the doomsayers back then were confusing temporary cyclical reverses with long-term structural barriers to growth. Fortified by that experience, it is tempting to dismiss contemporary growth pessimism as yet another case of the boy who cried wolf.

It is worth remembering, however, that the wolf does show up at the end of the story. So is it possible that, notwithstanding false alarms in the past, the doom-and-gloomers have a point this time?

Yes, I believe they do. The evidence is strong that conditions for long-term economic growth in the United States are decidedly less favorable today than they were in decades past. In other words, growth is getting harder. Consequently, *holding public policies constant* (a very important conditional!), we should expect growth rates in the foreseeable future—say, the next couple of decades—to be lower than those that prevailed throughout the 20th century.

It is important to note the time horizons of this assessment. I am not focused here on possible short-term factors that may be contributing to the current weak recovery from the Great Recession—for example, a continued shortfall in aggregate demand or deleveraging in the wake of a serious financial crisis. At issue here is not the gap between current and "potential" or full-employment output, but rather the gap between the future growth rate in potential output and the long-term historical trend line.

Most of the discussion sparked by Cowen and Gordon has focused on their claims that big new technological breakthroughs have been petering out. However, the case for pessimism about U.S. growth prospects presented here does not rest on such claims. Rather, a close empirical examination of long-term and recent trends in the conventionally measured components of economic growth reveals that all of those components have been weakening. A quick turnaround in enough of those sources to keep the U.S. economy on its prior long-term growth path appears distinctly improbable. As a result, the sluggish performance of the economy since the Great Recession is likely to persist in the coming years.

To understand the basis for this conclusion, let's break down measured economic growth—typically expressed as the annual rate of increase in real, or inflation-adjusted, gross domestic product (GDP) per capita—into the constituent elements tracked by conventional growth accounting: (1) growth in labor participation, or annual hours worked per capita; (2) growth in labor quality, or the skill level of the workforce; (3) growth in capital deepening, or the amount of physical capital invested per worker; and (4) growth in so-called total factor productivity, or output per unit of quality-adjusted labor and capital.[3]

Over the course of the 20th century, these various components fluctuated in their contributions to overall growth. The fluctuations, however, tended to offset each other, so that the long-term trend line of real per-capita growth held remarkably steady at around 2 percent per year. In the 21st century, this pattern of offsetting fluctuations has come to a halt as all growth components have fallen off simultaneously.

Hours worked per capita had been buoyed by a rising labor force participation rate caused by the century-long influx of women into the paid work force. But labor force participation began falling from its 2000 peak even before the Great Recession and has plunged since then. Even if we get back to the old peak, further progress will be difficult—and further progress on the scale of past gains is mathematically impossible. Labor quality or skill levels benefited from big increases in formal schooling during the 20th century, but more recently gains in educational attainment have slowed and, in some cases, even gone in reverse. The high-school graduation rate is actually lower today than it was in the early 1970s, while growth in the college completion rate since 1980 has been much slower than over the prior decades. Meanwhile, the rate of net investment in physical capital has been steadily slipping for decades, dragged down by a falling savings rate. And total factor productivity growth, after collapsing in the 1970s, revived for a decade beginning in the mid-1990s but has slumped again since then.

The simultaneous weakening of all the components of economic growth does not mean that slow growth is inevitable from here on out. The trends for one or more of them could reverse direction tomorrow. Nevertheless, it is difficult to resist the conclusion that the conditions for growth are less favorable than they used to be. The rise in labor participation during the 20th century was a one-time achievement that cannot be replicated on the same scale. Likewise with the rise in formal schooling: there is a limit to how many years spent out of the workforce in school can ultimately pay off in terms of higher lifetime output. Accordingly, it is hard to see how future gains in human capital accumulation can exceed or even match what has already occurred.

Note that the conclusion presented here that growth is getting harder does not depend at all on the claim by Cowen and Gordon that we are running out of big new ideas for improving consumer welfare. Pessimism about future growth prospects for the U.S. economy does not require a belief that innovation is in some long-term secular decline. Rather, it requires only the belief that innovation will not surge so much as to counteract the negative effects of the other factors mentioned above. And that belief is buttressed by solid evidence that innovation is getting harder as well.

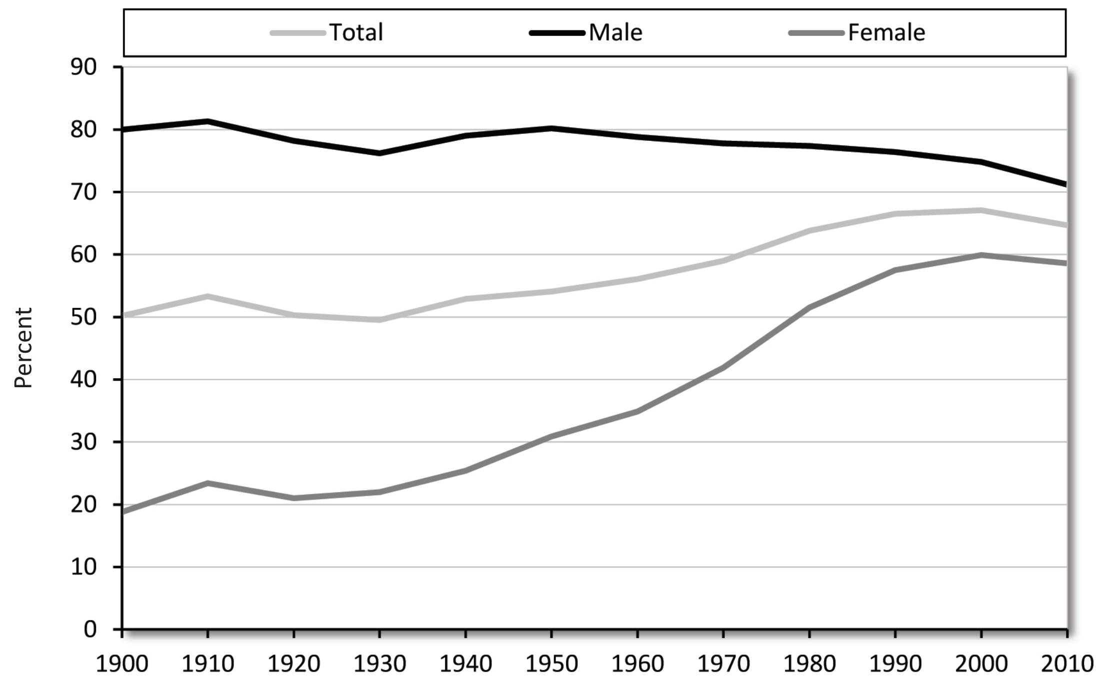
What are the policy implications of this analysis? It follows that, if conditions for growth really have deteriorated, then the public policies that delivered a certain rate of growth in the past will no longer suffice to maintain that growth rate in the future. In other words, policies that are more friendly to long-term growth will be needed if more robust growth is to be revived. In the quest to improve the U.S. economy's growth prospects, the lowest-hanging fruit now appears to be policy change.

Labor Force Participation and Hours Worked per Capita

All other things being equal, any growth in the labor force translates into growth in GDP: more workers equal more output.

Pessimism about future growth prospects for the U.S. economy does not require a belief that innovation is in some long-term secular decline.

Figure 1
Labor Force Participation Rate by Gender



Source: Historical Statistics of the United States, 2013 Economic Report of the President.

The steady movement of women out of the home and into the paid workforce powered a significant increase in the labor force participation rate.

But to result in higher GDP per capita, the labor force has to grow faster than the overall population. In other words, the labor force participation rate (LFPR) needs to rise. Thus, one way of achieving a higher GDP per capita is for a higher percentage of the population to be engaged in making GDP.

Over the course of the 20th century, the U.S. economy benefited from precisely this dynamic. Specifically, the steady movement of women out of the home and into the paid workforce powered a significant increase in the labor force participation rate—that is, the percentage of working-age Americans that are engaged in paid employment or actively looking for work. As shown in Figure 1 and Table 1, the female LFPR rose from only 18.8 percent in 1900 to 59.9 percent in 2000. As a result, the overall LFPR jumped from 50.2 percent to 67.1 percent.[4]

But the year 1999, as it turns out, currently stands as the high-water mark of women in the work force. Female LFPR dipped cyclically during the 2001 recession, but then never regained (much less exceeded) its pre-recession levels.

Male LFPR, meanwhile, has been falling gradually for decades due to delayed entry into the work force because of more years spent in school, increasing life expectancy, and earlier retirement, with the latter two yielding more years spent in retirement. As a result, overall LFPR stood at 66.0 percent in 2007 on the eve of the Great Recession—down from the 67.1 percent peak that held from 1997–2000 and lower than it had been since 1988. The Great Recession and the ensuing sluggish recovery pushed overall LFPR all the way down to 63.7 percent by 2012—lower than at any time since 1979.[5]

Accordingly, robust growth in participation will be needed just to get back to the peak level of 2000. Any efforts to boost labor-force participation, however, will have to contend with the aging of the population and the shrinking, relative to the entire adult

Table 1
Labor Force Participation Rate by Gender (Percent)

	Total	Male	Female
1900	50.2	80.0	18.8
1910	53.3	81.3	23.4
1920	50.3	78.2	21.0
1930	49.5	76.2	22.0
1940	52.9	79.0	25.4
1950	54.1	80.2	30.9
1960	56.1	78.8	34.9
1970	59.0	77.8	41.9
1980	63.8	77.4	51.5
1990	66.5	76.4	57.5
2000	67.1	74.8	59.9
2010	64.7	71.2	58.6
2012	63.7	70.2	57.7

Source: Historical Statistics of the United States, 2013 Economic Report of the President.

population, of the cohort of prime working-age adults. Labor-force participation is typically highest between the ages of 25 and 54, as younger adults are more likely to be in school and older adults are more likely to be retired. As of 2000, the prime-working-years age bracket constituted 43.6 percent of the total population, while the 55-and-over age bracket accounted for 21.1 percent. In that year, the oldest baby boomers were 54, so the entire baby-boom generation was in its prime working years. As we move forward in time, however, baby boomers start moving into the older age bracket and the relative size of the prime-working-years age bracket starts to shrink. Thus, by 2010, the 25–54 bracket had shrunk to 41.2 percent and the 55-and-over bracket had grown to 24.9 percent.[6] According to projections by the Bureau of the Census, in 2020 the 25–54 bracket will have declined further to 38.4 percent while the 55-and-over bracket will have risen to 28.7 percent.[7]

The most comprehensive measure of how hard Americans collectively are working for pay (and thus to produce GDP) is not the LFPR, but rather annual hours worked per capita. This broader measure reflects not only the LFPR but also the average hours worked per year by each member of the labor force. Figure 2 and Table 2 show the historical trends.[8] Putting aside the big plunge during the Great Depression and the big spike during the mobilization of World War II, the overall picture is one of a gradual decline between 1900 and 1964, a gradual rise between 1964 and 2000, and a resumption of decline so far in the 21st century.

This is a rather different picture than the steady rise in LFPR over the course of the 20th century. So what explains the difference? In particular, why were average annual hours worked per capita falling during the first six-plus decades even as the LFPR was steadily climbing? For one thing, average weekly working hours per employed person

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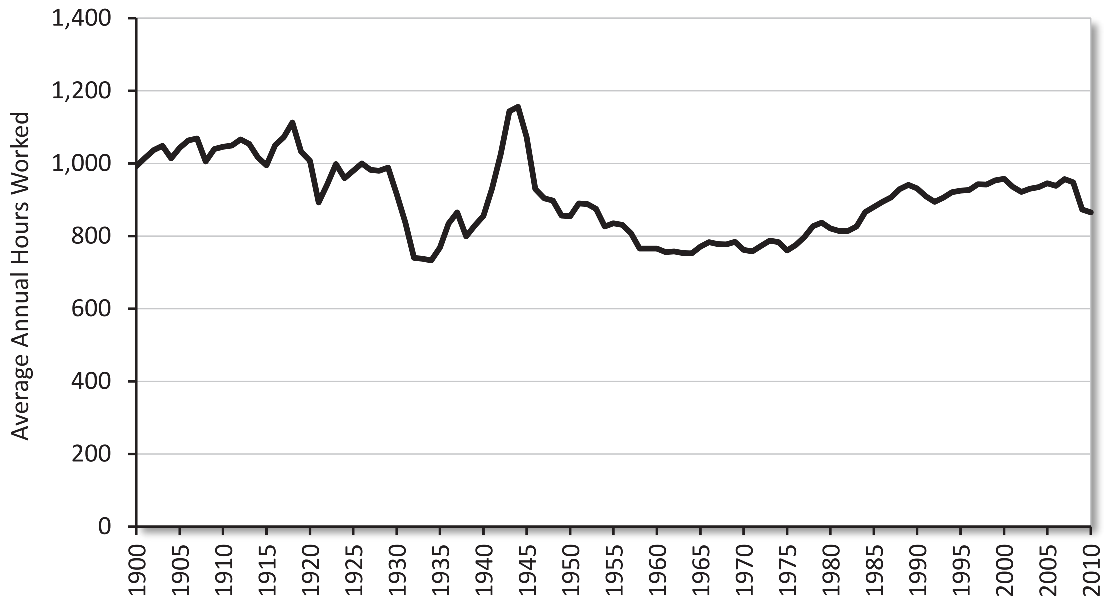
Figure 2
Average Annual Hours Worked Per Capita



Source: Valerie Ramey, Current Population Survey.

Table 2
Average Annual Hours Worked Per Capita

Years	Average Annual Hours Worked per Capita
1900–1909	1032.8
1910–1919	1049.4
1920–1929	973.0
1930–1939	805.8
1940–1949	977.1
1950–1964	808.2
1965–1979	783.5
1980–1989	869.4
1990–2000	927.9
2001–2011	922.7

Source: Valerie Ramey, Current Population Survey.

declined significantly during the 20th century as better-paid workers opted to "purchase" more leisure—an increase in welfare that doesn't show up in the GDP statistics. But much of the apparent rise in leisure actually represents a big shift of younger

Americans out of the work force and into secondary and postsecondary schooling. Looking just at the population aged 14 and older, the increase in average hours spent in school amounted to 37.5 percent of the decrease in average hours worked.[9] This increase in schooling is best understood, not as consumption like leisure, but as investment in human capital. It therefore contributed to higher growth in the form of increases in both labor quality and productivity.[10]

In any event, the last third of the 20th century witnessed a clear and substantial rise in annual hours worked per capita—a 27 percent increase between 1964 and 2000. During this period, the rise in labor intensity provided a substantial boost to overall economic growth. Between 2000 and 2010, by contrast, average annual hours worked per capita fell by 10 percent. And when labor intensity is falling, that means the other components of growth must compensate or overall economic performance will suffer.

How important is all of this? Compare the growth records of two periods: 1973–1990 and 1990–2007. Both are periods of 17 years; both began and ended in the last year of an economic expansion. The earlier period included oil shocks, stagflation, a deep recession in the early 1980s, and disappointing growth in labor productivity at an average annual rate of only 1.33 percent. By contrast, the latter period experienced only two mild recessions while labor productivity growth, fueled by advances in information technology, surged to an average annual rate of 2.33 percent.[11] Nevertheless, annual growth in real GDP per capita averaged 1.93 percent during 1973–1990—slightly better than the 1.85 percent average annual growth that prevailed during 1990–2007.[12] How was that possible?

The answer lies in the recent turnaround in labor participation and intensity. Between 1973 and 1990, the LFPR climbed from 60.8 percent to 66.5 percent; between 1990 and 2007, it dipped slightly to 66.0 percent. Meanwhile, average annual hours per capita rose 18.2 percent during the earlier period, compared to only a 2.8 percent increase during the more recent period.

A 2011 report by the McKinsey Global Institute provides an estimate of the impact of changing labor force growth on overall GDP growth. According to the report, the expansion of the work force contributed an average of 1.9 percentage points to total annual GDP growth (not GDP per capita) during the 1960s, 2.0 percent during the 1970s, 1.7 percent during the 1980s, and 1.6 percent during the 1990s. From 2000 to 2010, however, labor force growth accounted for an average of only 0.4 percentage points of annual GDP growth, and it is predicted that it will add only 0.5 percentage points to annual GDP growth, on average, between 2010 and 2020.

Because of the less favorable demographic trends, the researchers at McKinsey Global Institute estimate that growth in output per worker (which includes improvements in labor quality, capital deepening, and total factor productivity) will have to improve by 34 percent to maintain GDP growth at the rates to which we are accustomed.[13] As we shall see in the following sections, that is a tall order.

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Human Capital Slowdown

The concept of labor participation treats workers as fungible: each full-time employee counts the same, and each hour worked counts the same. In reality, of course, some workers are much more valuable than others depending upon education, experience, and overall skill level. Thus, when evaluating the effect of more or fewer workers on total output, we need to look not only at the quantity of labor supplied but also the quality of labor as well.

Measuring the quality of labor is tricky, as anyone who has sat on either side of the desk during an annual performance review can surely attest. The primary way that economists set about this task is to look at market signals—specifically, the differences in wages paid to workers with different edu-

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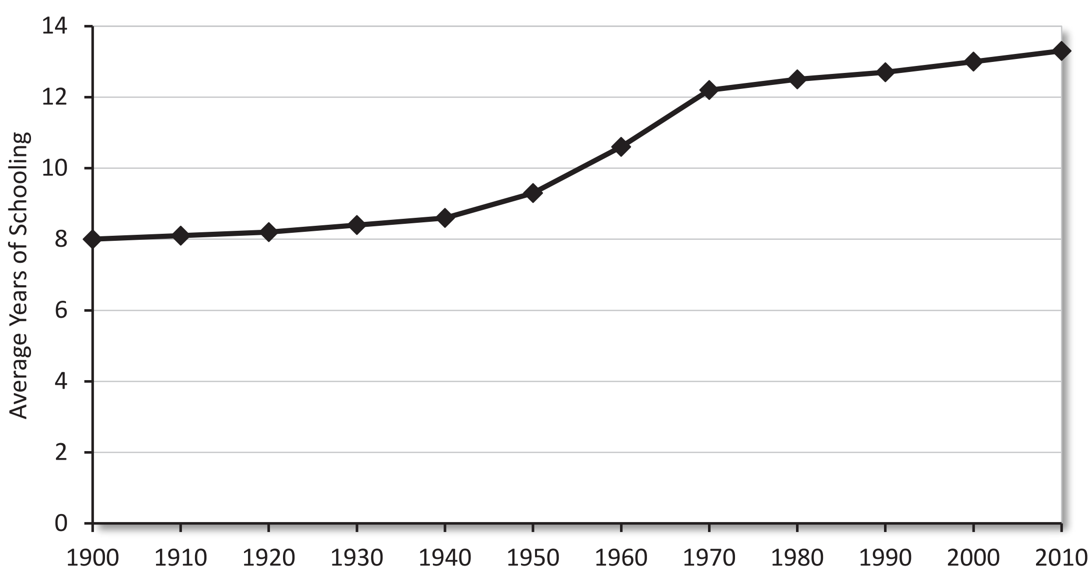
cation and experience levels. Since better educated and more experienced workers earn higher wages, it is assumed that those workers are more productive and thus that their labor hours total a correspondingly higher number of "effective" or quality-adjusted "labor units" than an equivalent number of hours worked by less educated, less experienced workers.

The big story concerning U.S. labor quality during the 20th century was a dramatic rise in the years spent in school by American workers. In 1900, the ratio of new high school graduates to 17-year-olds was only 6 percent; by 1970 that figure had climbed to 76 percent.[14] The ratio of new college graduates to 23-year-olds was only 2 percent in 1900; by 1940 the fraction of 25 to 34-year-olds with college degrees stood at 6 percent, and by 1980 the figure had risen to 24 percent.[15] Overall, as shown in Figure 3, the average years of school completed for Americans 25 years old and over rose by 63 percent between 1900 and 2000—from 8.0 years to 13.0 years.[16]

Economists estimate that the impact of this education boom on economic growth was significant. According to Harvard economists Claudia Goldin and Lawrence Katz, the direct effect of increased educational attainment on labor quality accounted for about 15 percent of the total rise in real GDP per capita over the period 1915–2005.[17] Other economists using similar methods have reached similar results.[18]

This source of growth, however, has been waning in recent decades. The high school graduation rate is actually lower now than it was in 1970; meanwhile, although college attainment for young women has continued to rise, college attainment for young men is roughly the same today as it was in 1980.[19] According to Goldin and Katz, the mean years of schooling completed by American workers rose from 9.01 in 1940 to 12.46 in 1980—for an average growth rate of 0.81 percent per year. Between 1980 and 2005, by contrast, mean years of schooling completed increased further to 13.54—for an average growth rate of only 0.33 percent per year.[20] Accordingly,

Figure 3
Average Years of Schooling (Americans Aged 25 and Older)



Source: National Center for Education Statistics, Current Population Survey, United Nations Development Programme.

labor quality growth due to rising schooling levels fell off from an average annual rate of 0.59 percent per year during 1940–1980 to 0.37 percent during 1980–2005.[21] In other words, education's direct contribution to economic growth fell by 37 percent.

Looking ahead, labor quality growth is projected to decline further. According to Dale Jorgenson of Harvard, labor quality growth due to both increased schooling and rising levels of worker experience (due to the aging of the population) averaged 0.47 percent a year during 1990–2010. But between 2010 and 2020, Jorgenson projects, stabilization of educational attainment and the ongoing retirement of the baby boomers will bring labor quality growth to almost a complete halt—with an average increase of only 0.06 percent a year.[22]

The analysis discussed here is subject to an important caveat. Namely, when economists estimate education's contribution to labor quality—and thus economic growth—on the basis of wage differentials, they are assuming that more schooling actually *causes* higher productivity as opposed to merely *signaling* it. Sure, workers with college degrees earn higher pay than less educated workers, but why? Is it because the skills they learned in college make them more valuable in the workplace? Or do employers pay more for workers with college degrees because those degrees are a signal that the workers who earn them have preexisting abilities (intelligence, conscientiousness) that firms value?[23]

To the extent that the signaling theory of education wage premiums is true, rising educational attainment does not reflect increasing levels of human capital, but merely indicates an ongoing signaling "arms race" in which talented workers need to spend more and more time in school in order to demonstrate their higher quality to potential employers. In that case, economists are wrong to assume that workers with more schooling in one period have higher skills than workers from an earlier period with less schooling. And consequently, slowing growth in educational attainment does not mean that an important source of growth—rising labor quality—is drying up. Indeed, it may be possible to improve growth prospects by reducing the average number of years workers spend in school—years they could spend being productive in the workplace and honing actual skills through on-the-job experience.

So is the signaling theory true? There is good evidence that signaling explains at least some of the higher wages earned by workers with more schooling. In particular, there is the existence of the so-called "sheepskin effect": returns to completing the 12th or 16th year of school are much higher when doing so is accompanied by earning a high school or college diploma.[24] This fact suggests that degree completion is a signal of underlying abilities that are rewarded over and above the compensation for completing X years of coursework.

On the other hand, it is clear enough that signaling is not the whole story. Even if we might be puzzled at how exactly a liberal arts college education boosts worker productivity, in many other cases—from instruction in basic literacy and numeracy in primary school to graduate education in math, the sciences, engineering, and medicine—the connection between schooling and the acquisition of economically valuable knowledge and skills is obvious.

More broadly, it is well established that general intelligence, as measured by IQ tests, is a good predictor of both job performance and earnings. And there is powerful evidence that schooling improves IQ. Particularly interesting are a number of "natural experiments" in which some students, for reasons outside their control, spent less time in school than their peers. These less-schooled students scored lower on IQ tests—and the deficits rose as the schooling gaps increased.[25] Such natural experiments control for the possibility that the association between years of schooling and IQ is due merely to the fact that more intelligent students choose to stay in school longer.

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Conditions for growth in the 21st century will be less favorable because of the slowdown in the growth of educational attainment.

But if signaling explains even part of the education wage premium, that means that estimates of education's impact on productivity based on wage premiums will overstate that impact. Fair enough, but at the same time estimates based on wage premiums will understate education's impact to the extent that education generates productivity-enhancing externalities not captured in the wages of those workers who receive the schooling. And there are good reasons for believing those externalities do exist. For example, the economist Enrico Moretti has found that workers in cities with higher percentages of college-educated workers earn higher pay than workers in cities with less-educated workforces—and, furthermore, that the biggest gains accrue to less-educated workers.[26]

For present purposes, the key question is whether increases in schooling cause increases in economic growth—in other words, whether the private return to education in the form of higher wages is matched by a social return to education in the form of higher GDP per capita. After all, if the signaling theory explains all the private return, the social return would be minimal or zero.[27] At this point the economic evidence remains mixed. Earlier cross-country studies failed to find any growth effect from schooling,[28] but subsequent investigation has concluded that those studies were plagued by measurement errors due to poor quality data on educational attainment.[29] A more recent cross-country study that aims to reduce those measurement errors does find a social return to education in line with private returns.[30] In addition, a study that assesses the effect of differences in compulsory schooling laws among U.S. states finds social returns of greater secondary schooling slightly in excess of private returns.[31]

Accordingly, there are strong reasons for believing that the dramatic increase in schooling over the 20th century did contribute materially to economic growth. It follows, therefore, that conditions for growth in the 21st century will be less favorable because of the slowdown in the growth of educational attainment.

Meanwhile, the conclusion that human capital constraints on growth are tightening still holds even if one assumes that the signaling theory is completely true and the social returns to education are zero. In that hypothetical scenario, the relative supply of high-ability workers would be fixed. However, the relative demand for high-ability workers has been steadily rising, as evidenced by the growing share of total employment accounted for by managers and professionals. These positions, which typically require high levels of human capital, soared from 10 percent of total jobs in 1900 to 30 percent in 2000.[32] At the outset of the 20th century, there would have been a substantial reserve of such workers that could accommodate the rising relative demand for human capital. That reserve would now presumably be exhausted, or else soon would be, in which case continued increases in the demand for skill would push the wage premium for skilled workers ever higher, unmitigated by any supply response. Over time, this rising premium would force producers throughout the economy to substitute away from high ability to an ever-increasing extent—with attendant costs that would render growth rates lower than they otherwise might have been.

Declining Saving and Investment Rates

The concept of human capital represents an extension of the older, more familiar idea of physical capital—that is, the plant and equipment that augment human labor in the production of goods and services. The central importance of capital to capitalism is obvious enough: the immense gains in output made possible by investment in productive assets, and the leading role of the investors in determining what gets produced and how, so distinguished the modern market economy from what came before as to give this economic system its most popular and enduring name.

The connection between capital accumulation and economic growth is twofold. First, the technological progress that is the ultimate driver of long-term growth typically is embodied in new capital: new machines that make new products or enable new, more efficient production processes. Second, "capital deepening," or an increase in the amount of plant and equipment per worker, can improve output per worker-hour even within the existing technological frontier. There is nothing new or innovative about a backhoe, but giving one to a ditch digger who previously used only a shovel will result in a dramatic increase in his hourly output.

Thus, according to neoclassical growth theory, higher levels of investment in physical capital will lead to higher levels of output—subject, however, to diminishing returns. Accordingly, an increase in the investment rate that boosts the ratio of capital to labor can lead to temporary increases in the growth rate. Meanwhile, endogenous growth models—which seek to explain the process of innovation that overcomes diminishing returns and thus powers long-term growth—link higher levels of investment to innovation and thus to increases in the long-term growth rate.

Of course, a rise in investment does not lead automatically to higher output. Bad investments, after all, merely waste resources that otherwise could have been productively invested, or at least consumed. Accordingly, the value of a given level of investment is contingent upon the laws and institutions that shape investment incentives. High investment levels combined with dysfunctional policies and institutions may translate into more waste, not greater output and higher growth rates. The failure to recognize this possibility lay behind the once-widespread view that centrally planned economies would outperform market economies because, through forced savings, they could achieve higher rates of investment. Alas, the very institutions that made it possible for central planners to boost investment rates also ensured that much of the investment would be misdirected.

With that caveat in mind, for present purposes there is a reasonable basis for associating a higher rate of investment with stronger prospects for economic growth. At the very least, one can say that there is no basis for believing that a declining rate of capital accumulation is a positive sign for future growth prospects. And since the rate of U.S. capital accumulation has been in long-term decline for decades, here is yet another reason for concluding that growth is getting harder.

Figure 4 tells the story.[33] Net national investment (i.e., investment net of depreciation charges) as a percentage of net national product has been slipping steadily for decades, in line with the more widely reported fall in the national savings rate. U.S. investment, of course, is not entirely dependent on domestic savings as the country has been running a capital surplus (i.e., current account deficit) for decades. But even with the large influx of foreign investment, the steep fall in national savings has sufficed to drag down the rate of capital accumulation.

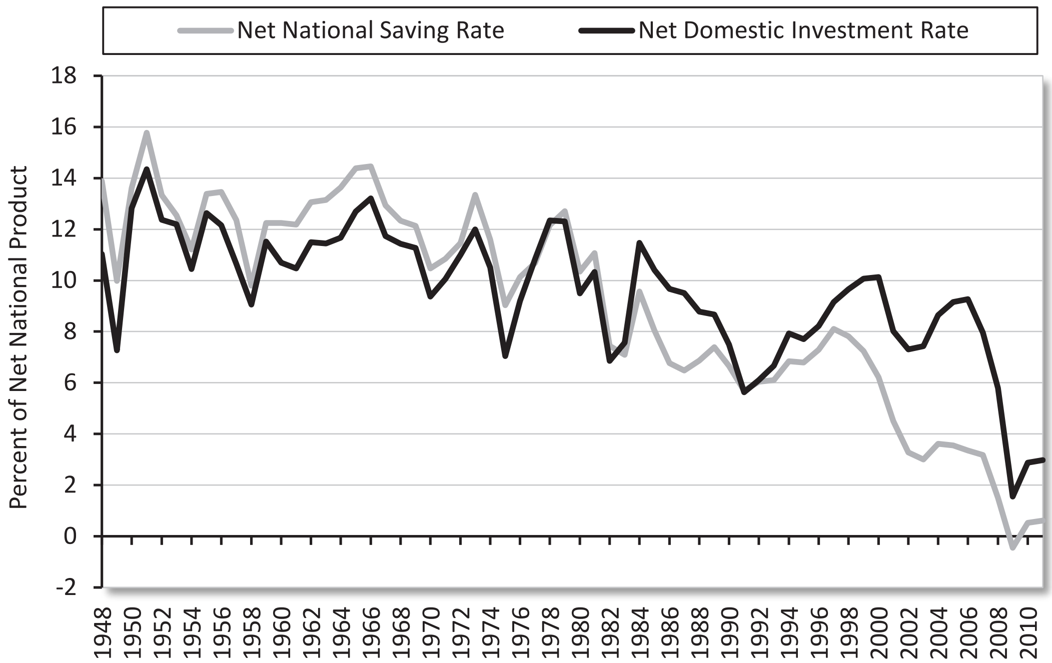
Net national investment (i.e., investment net of depreciation charges) as a percentage of net national product has been slipping steadily for decades.

Innovation to the Rescue?

The long-term future of economic growth hinges ultimately on innovation. Any given input of labor or capital is subject to diminishing returns, so that at some point further additions of that input will yield no additional increment of output. To keep growth going, it is therefore necessary to devise new products or production processes that can coax additional output out of a given set of inputs. Economists track the output-enhancing effects of innovation with a measure known as total factor productivity (TFP) growth.

In the current situation, it appears that only a surge in TFP can keep U.S. economic growth from faltering. After all, labor hours per capita are falling, the improvements in worker quality that boost effective labor in-

Figure 4
Saving and Investment Rates



Source: Bureau of Economic Analysis.

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puts are slowing down, and the rate of capital accumulation has been falling steadily.

Can innovation come to the rescue? Predicting the future growth of TFP is a mug's game: shifts in the pace and direction of technological change are notoriously difficult to see coming, and furthermore the relationship between such shifts and movements in TFP is anything but straightforward. All we can do is examine the long-term and recent trends in TFP growth and then make our best guess about what the future holds. Such analysis cannot rule out the possibility that a dramatic acceleration in output-enhancing innovation is waiting just around the corner, but there is no evidence that it is currently under way.

Calculating productivity growth is fraught with methodological difficulties.[34] In the first place, it is noteworthy that TFP is not calculated directly. Known also as the "residual" and sometimes dubbed "the measure of our ignorance," TFP is simply a catch-all measure of output not otherwise attributed to increases in labor or capital.[35] It is entirely possible, therefore, that some of the output-enhancing effects of innovation end up being attributed to input growth. For example, new equipment purchases counted as increases in capital can embody big technological changes, and the value of quality-adjusted labor can reflect increases in productivity made possible by organizational changes.

Meanwhile, tracking changes in real or inflation-adjusted output often comes down to educated guesswork. For any given increase in nominal or current-dollar value-added, a determination must be made as to what portion is due to a real increase in output and what portion simply reflects price increases. In the case of producers of homogeneous commodities with unchanging quality, this exercise is simple enough: just count up the widgets made each year. But when a new, more expensive smart phone comes out, how much of the price increase is for the extra features and how much is simply inflation? And in a year-on-year comparison of net revenues for the management consulting industry, how does one even conceptualize what might constitute changes in quality or output volume?

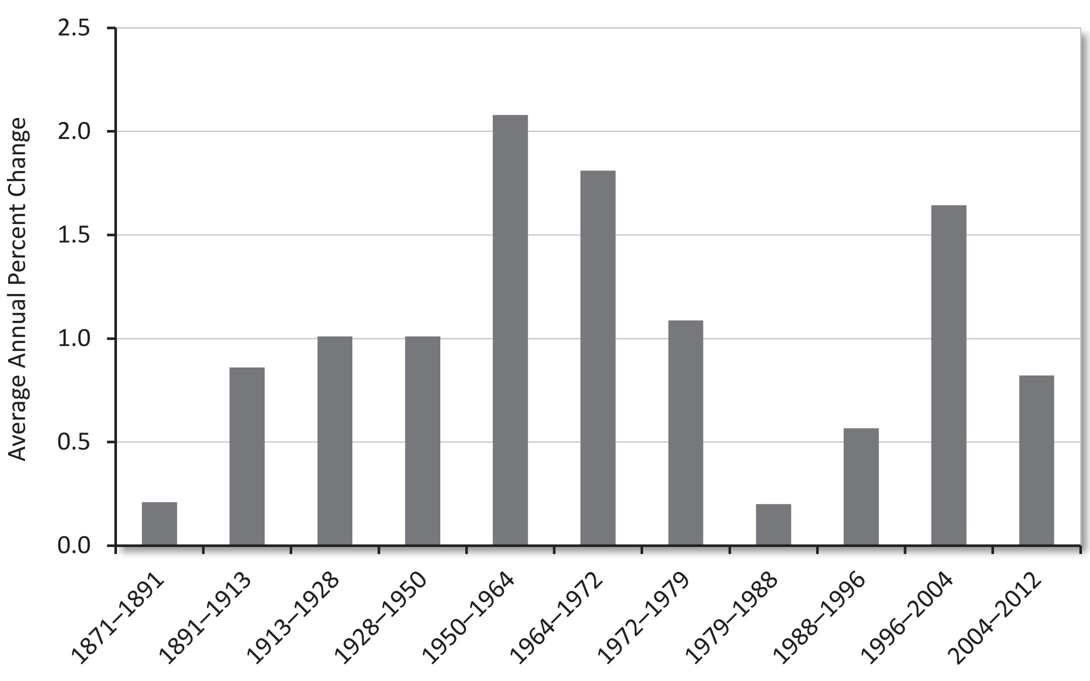
Fortunately, measurement problems at the industry level are somewhat ameliorated at the aggregate level. Many of the industries for which determining real output growth is most intractable are providers of producer goods and services (like, for example, management consultants) that are not part of final output. If their productivity growth is understated, the productivity growth of their customers is correspondingly overstated so the net effect is a wash. Furthermore, estimating overall changes in the price level—while anything but an exact science and subject to endless wrangling—is nonetheless a more tightly bounded problem than disentangling price from quantity changes in many specific industries. Finally, since the goal here is to measure changes in TFP over time, errors in measuring output wash out to the extent that the degree of error remains constant.

With an appropriate pinch of salt added to the data, let's now look at the trends in TFP growth. The best available estimates reveal a distinctive pattern to its ebbs and flows since the emergence of the modern mass production/mass distribution economy in the late 19th century. Figure 5 reveals "one big wave"[36] of TFP growth from 1870 to 1995, followed by a smaller wave that began in the mid-1990s.[37] TFP growth started low at the outset of the period, rose during the early decades of the 20th century, peaked during the middle decades, and then fell off again in the 1970s. TFP growth surged again from 1996 through 2004 but then has slacked off in more recent years.

There is no generally accepted explanation of TFP growth's rise and fall over the

There is no generally accepted explanation of TFP growth's rise and fall over the course of the 20th century.

Figure 5
Total Factor Productivity



Source: Robert Gordon, Bureau of Labor Statistics.

Economists generally agree that information technology was behind the decade of high TFP growth that ran from the mid-1990s to the mid-2000s.

course of the 20th century. The productivity slowdown that began in the 1970s—afflicting not just the United States, but advanced countries around the world—sent economists scrambling for answers, but no single overarching theory or combination of partial explanations has won broad favor within the profession. For example, higher energy prices, inflation more generally, and new environmental, health, and safety regulations were all identified as possible culprits during the 1970s, yet low TFP growth persisted in the 1980s even in the face of falling energy prices, disinflation, and substantial deregulation.

Another possible explanation is that what appeared as a drop in TFP growth was just an artifact of measurement error. The broad consensus of researchers who have examined this possibility, however, is that, while possible measurement errors abound, they have not been getting systematically worse—at least not enough to explain more than a fraction of the slowdown.[38]

Both Tyler Cowen and Robert Gordon argue that the productivity slowdown of recent decades reflects the progressive exhaustion of the output-enhancing potential of the great technological breakthroughs of the late 19th and early 20th centuries—and the failure of further breakthroughs of equivalent potential to materialize. In particular, Gordon identifies four clusters of innovations from that era: electricity, including electric lighting, motors, and appliances; the internal combustion engine, including automobiles, airplanes, supermarkets, and suburbs; "rearranging molecules," including petrochemicals, plastics, and pharmaceuticals; and communications, including telephony, movies, radio, and television.[39] According to Gordon, these veins of innovation were so rich that they could be "mined" productively for decades. But by the 1970s the biggest potential improvements had already been exploited and so productivity growth began to sputter. This view, while both provocative and plausible, is by no means generally accepted.

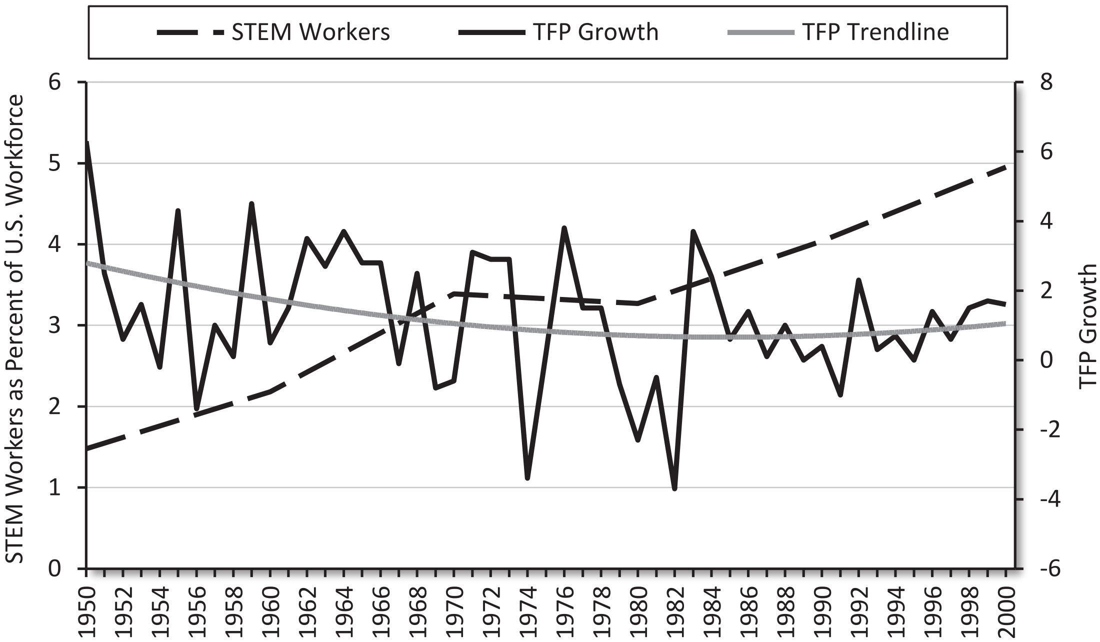
Although the exact causes of the post-'70s productivity slowdown remain obscure, economists generally agree that information technology (IT) was behind the decade of high TFP growth that ran from the mid-1990s to the mid-2000s. From 1996 to 2000, the TFP surge was driven primarily by rapid productivity gains in the production of IT; from 2000 to 2004, the locus of the most impressive TFP gains shifted to IT-using industries that had invested heavily in new technology and complementary organizational changes during the 1990s.[40] Since 2004, however, a drop-off in IT investment and slower productivity gains in IT production have caused TFP growth to subside back to pre-1996 levels. It should be noted that this most recent TFP slowdown predates the Great Recession and thus cannot simply be blamed on cyclical factors.

Was the IT revolution that has transformed our lives in so many ways really only good for a decade of strong productivity growth? Or is the current TFP slump merely a breathing spell in a long-term resurgence? Gordon, for his part, is pessimistic: he regards the IT revolution as decidedly less transformative than the four big innovation clusters of the past, and furthermore he discounts the possibility of any transformative new breakthroughs that might emerge from other quarters. Cowen, meanwhile, is sympathetic to the view that continued progress in IT and elsewhere holds the potential to revive productivity growth in the longer term.[41]

The truth is, it's anybody's guess. Recent and careful review of the evidence, however, casts doubt on the likelihood of a sudden revival in TFP growth. Specifically, recent trends in semiconductor price and performance—which have been at the heart of the phenomenon known as "Moore's Law"[42] that has been the fundamental driver of the IT revolution—show that the rate of improvement has slowed down from the torrid pace achieved during the 1990s when the TFP growth resurgence was in full swing.[43]

Although a revival of robust productiv-

Figure 6
Science, Technology, Engineering, and Mathematics Employment and Total Factor Productivity



Source: Mark Regets and Lindsay Lowell, Bureau of Labor Statistics.

ity growth is certainly possible, it is nonetheless fair to say that the conditions for output-enhancing innovation are growing less favorable over time. Specifically, there is strong evidence that innovative activity is subject to diminishing returns. Consider the evidence provided in Figure 6, which juxtaposes TFP growth rates with the relative size of the science, technology, engineering, and mathematics (STEM) workforce, a decent proxy for workers who engage in innovative activity.[44] The percentage of the total workforce engaged in innovation has been rising steadily even as the total workforce grows, yet the increase in innovative activity has not been matched with any corresponding rise in productivity growth. On the contrary, productivity growth rates have generally been falling. The obvious conclusion is that innovation starts with the lowest-hanging fruit and gets progressively more difficult over time.[45]

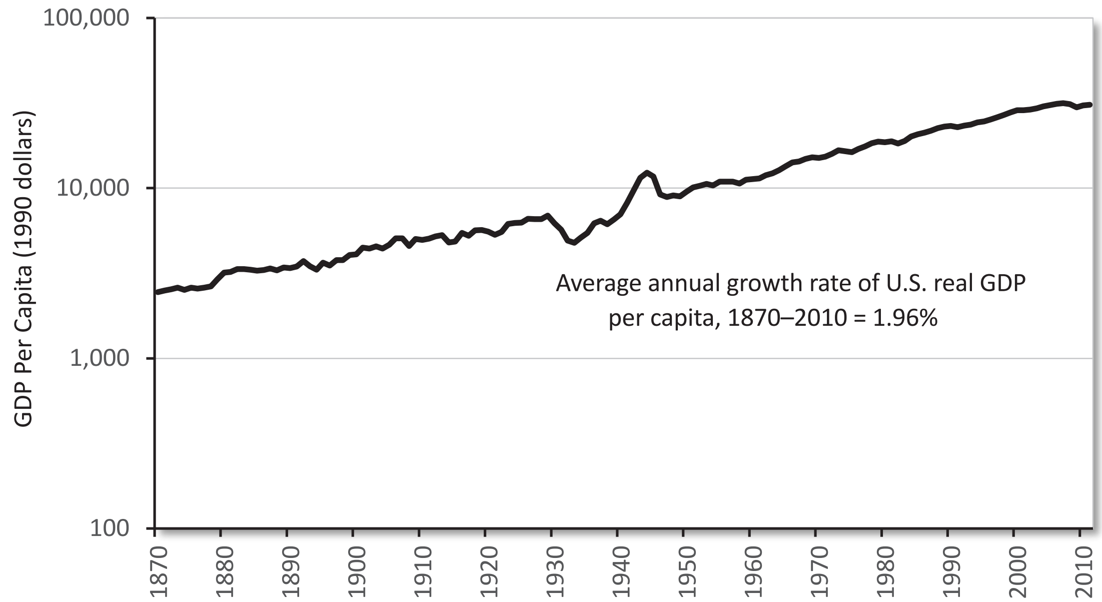
Conclusion

Figure 7 shows the rising level of real (i.e., inflation-adjusted) GDP per capita in the United States between 1870 and 2010.[46] What jumps out at first glance is the remarkable stability of the growth path: other than a sharp decline during the Great Depression and a mirror-image spike in the 1940s, it hews closely to the long-term average rate of approximately 2 percent annual growth. The squiggles around that average represent the macroeconomic fluctuations of booms and busts that dominate headlines and popular perceptions. But this incessant short-term volatility masks a seemingly imperturbable long-term trend.

In contrast to the steadiness of the overall long-term growth rate, there has been considerable variability in the various components of GDP growth—notably, growth in hours worked per capita, labor quality as

Conditions for output-enhancing innovation are growing less favorable over time.

Figure 7
U.S. GDP Per Capita (log)



Source: Angus Maddison.

In contrast to the steadiness of the overall long-term growth rate, there has been considerable variability in the various components of GDP growth.

influenced by age and education levels, the rate of capital accumulation, and total factor productivity. Over the decades, however, the speed-ups and slowdowns of these growth components have tended to cancel each other out. Thus, hours worked per capita fell steadily over the first six decades of the 20th century, just as education levels and TFP were surging. In the 1960s and '70s, the influx of women and young baby boomers into the work force ramped up labor hours per capita just as TFP dropped off sharply. That same influx of less experienced workers had canceled out a steep rise in average years of schooling to render overall labor quality growth fairly constant during those decades, but then in the 1980s and '90s the move of the boomers into their prime earning years helped to offset a slackening pace of increases in educational attainment.

At present, however, all the components of growth appear to have slowed at the same time. Hours worked per capita have been falling since the beginning of the 21st century, and even if 2000-era levels can be regained, the prospects for further growth look limited. The combination of slackening gains in schooling and retiring baby boomers means that labor quality will remain more or less flat for the foreseeable future. There is no reason to believe that the long-term decline in the net national investment rate will be reversed anytime soon. Meanwhile, a temporary resurgence in TFP after decades of mysterious sluggishness petered out years ago. Consequently, there are strong reasons to expect that average real growth in U.S. GDP per capita over the coming years will fall short of the historical norm of 2 percent.

Recent projections of the U.S. growth rate over various conceptions of the long run confirm this assessment. Table 3 summarizes the results. Robert Gordon, updating a 2006 projection in 2010, examines the period 2007–2027; Dale Jorgenson, writing in 2013, looks at the potential U.S. growth rate (i.e., growth assuming full employment of resources) during the period 2010–2020; John Fernald of the Federal Reserve Bank of San Francisco estimates the steady-state growth rate over an unspecified long term in a paper published in 2012; a 2013 Congressional Budget Office projection looks ahead to the period 2019–2023; the most recent projections by the Federal Reserve Board members and Federal Reserve Bank presidents, made in June 2013, look at GDP growth over an unspecified "longer run."[47] Except for Gordon, all the projections were for growth in overall GDP, not GDP per capita; Gordon took the additional step of projecting population growth to arrive at an estimate of per capita growth. For the other projections, per capita growth rates have been derived using the most recent Census Bureau projections for U.S. population growth.

All of these projections show long-term growth in real GDP per capita falling well below the historical norm of 2 percent per year. Of course these are only projections, and events could certainly turn out better than predicted. But the analysis provided in this paper provides strong reasons for thinking that the general thrust of these projections is on target. Accordingly, even assuming that the messy aftermath of the Great Recession can be successfully put behind us, a marked and historically abnormal slowdown in the potential growth of the U.S. economy still awaits us.

How important is such a slowdown? Thanks to the power of compound interest, relatively small differences in the growth rate add up to huge differences in living standards over time. Using the so-called "rule of 70," you can figure out roughly how long it takes for output per person to double by dividing 70 by the growth rate. Thus, a 2 percent annual growth rate doubles incomes in 35 years, whereas with a 1.5 percent annual growth rate it takes 47 years for incomes to double. Consider the case of a 22-year-old college graduate, just starting in the workplace now. If the long-term average growth rate falls from 2 percent to 1.5 percent, the economy at the time our new college grad retires at age 65 will be almost 20 percent less wealthy than it would have been if the growth rate had remained on trend.

Of course, free individuals are under no obligation to maximize their country's growth rate. If people decide on their own to work fewer hours and devote more time to noncommercial pursuits, they have every right to do so, notwithstanding the impact on GDP. Indeed, the great value of economic growth is that it expands our choices: the richer we are, the easier it is to focus more on family, friends, hobbies, and community activities, and less on squeezing every possible dollar out of our waking hours.

Accordingly, a slowing economic growth rate is not a problem to the extent that it reflects shifting individual preferences. If, as people get richer, they choose to devote relatively less energy to efforts inside the cash nexus, then the measured value of goods and services exchanged within the cash nexus—that is, GDP—may suffer, but well-being will not. In particular, it may be that the continued progress of information technology will

At present, however, all the components of growth appear to have slowed at the same time.

Table 3
GDP Growth Projections

	Jorgenson (2010–2020)	Gordon (2007–2027)	Fernald (2023)	FOMC ("longer run")	CBO (2019–2023)
GDP (% Growth)	1.91	2.40	2.10	2.40	2.30
GDP Per Capita (% Growth)	1.05	1.58	1.36	1.63	1.55

Source: Dale Jorgenson et al., Robert Gordon, John Fernald, Federal Open Market Committee, Congressional Budget Office.

push more and more social activity outside the money economy. Traditionally, the great mutual benefits accruing to people from specialization and exchange were heavily dependent on coordination by the price system. But the advent of the Internet and the rise of online social networks have made it increasingly easy and attractive to organize and conduct large-scale collaborative activities involving highly intricate specialization without any money changing hands—think Wikipedia, or the open-source software movement. In the future, what has amusingly been called "dot communism" may end up displacing more and more social activity that was previously mediated by the money economy.[48]

But there is more to the story of slowing economic growth than the interplay of private, voluntary decisions. In addition, the public policies that provide the political and legal infrastructure of the U.S. economy play an important role. Those public policies are rife with barriers to entrepreneurship, competition, innovation, and growth: restrictions on new entry into markets, subsidies that favor entrenched incumbents over new entrants, taxes that blunt incentives to innovate and take risks, interference with the transmission of price signals, and various interventions that distort incentives to favor zero-sum rent-seeking activity over positive-sum efforts to reduce the cost and increase the value of goods and services.

The argument presented here is that, holding public policies constant, the U.S. long-term growth rate can be expected to falter because of deteriorating conditions for growth. But, of course, it is not necessary to hold public policies constant; rather, it is possible to change them for the better. Indeed, faltering economic dynamism may very well make such a move more likely by exposing to public view and scrutiny the negative impact of anti-growth policies. In the quest for new sources of growth to support the American economy's flagging dynamism, policy reform now looms as the most promising "low-hanging fruit" available.

In the quest for new sources of growth to support the American economy's flagging dynamism, policy reform now looms as the most promising "low-hanging fruit" available.

Notes

The author gratefully acknowledges the valuable research assistance provided by Stephanie Rugolo.

1. Tyler Cowen, *The Great Stagnation* (New York: Dutton, 2011).

2. Robert Gordon, "Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds," National Bureau of Economic Research Working Paper 18315 (August 2012).

3. Components (2), (3), and (4) combine to constitute average labor productivity, or output per worker-hour. Per capita GDP growth thus consists of the product of component (1) and average labor productivity—in other words, hours worked per capita times output per worker-hour.

4. Data from 1900–1970 are from United States Census Bureau, *The Statistical History of the United States from Colonial Times to the Present* (New York: Basic Books, 1976), Series D-13; data from 1980 forward are from *2013 Economic Report of the President*, Appendix B-39, http://www.whitehouse.gov/administration/eop/cea/economic-report-of-the-President/2013. The data include ages 10 and older for 1900–1930, 14 and older for 1940–1960, and 16 and older from 1970–2012. Data for 1900–1930 include the institutional population, data for 1940–70 include members of the armed services, and data from 1980–2012 include only the civilian noninstitutional population. Alaska and Hawaii began to be included in 1960.

5. *2013 Economic Report of the President* (Washington: White House, 2013), Appendix B-39.

6. *2012 Statistical Abstract of the United States* (Washington: U.S. Census Bureau, 2012), Table 7, http://www.census.gov/compendia/statab/2012/tables/12s0007.pdf.

7. Ibid., Table 9, http://www.census.gov/compendia/statab/2012/tables/12s0009.pdf.

8. Data from 1900–2005 come from Valerie Ramey, http://www.econ.ucsd.edu/~vramey/research.html. Data from 2006–2011 follow Ramey's methodology using the Bureau of Labor Statistics' Current Population Survey figures for civilian hours plus Ramey's figures for military hours divided by the U.S Census annual population figures.

9. See Valerie Ramey and Neville Francis, "A Century of Work and Leisure," *American Economic Journal: Macroeconomics 2009* 1, no. 2 (July 2009): 197 (Table 2), 201 (Table 3).

10. More education promotes innovation (and thus productivity growth) by increasing both the number of innovators (highly educated scientists and engineers) and the size of the market for innovation (more educated consumers are more likely to adopt new products and new technologies).

11. Labor productivity figures were taken from the database of the Bureau of Labor Statistics, http://www.bls.gov/lpc/#data.

12. Figures were derived from The Conference Board, Total Economy Database, http://www.conference-board.org/data/economydatabase/.

13. McKinsey Global Institute, *Growth and Renewal in the United States: Retooling America's Economic Engine* (February 2011), p. 20 (Exhibit 6), http://www.mckinsey.com/insights/mgi/research/productivity_competitiveness_and_growth/growth_and_renewal_in_the_us.

14. U.S. Census Bureau, *Statistical History of the United States*, Series H-599.

15. National Center for Education Statistics, *120 Years of American Education: A Statistical Portrait* (January 1993), Table 28, http://0-nces.ed.gov.opac.acc.msmc.edu/pubs93/93442.pdf; U.S. Census Bureau, *CPS Historical Time Series Tables* (Washington: U.S. Census Bureau), Table A-1, http://www.census.gov/hhes/socdemo/education/data/cps/historical/index.html.

16. Figures for 1900–1939 come from National Center for Education Statistics, *120 Years of American Education*, Table 5. Figures for 1940–1990 come from the Bureau of Labor Statistics' Current Population Survey, Table A-1. The figures for 2000–2010 come from United Nations Development Programme, "Mean Years of Schooling (of adults) (years)," http://hdrstats.undp.org/en/in dicators/103006.html. Data from 1900–1990 are a median measure, while those for 2000–2010 are a mean measure. The figure for 1900 is estimated based on data from 1910 forward.

17. Claudia Goldin and Lawrence F. Katz, *The Race between Education and Technology* (Cambridge, MA: Belknap Press of Harvard University Press, 2008), p. 40.

18. See Dale W. Jorgenson and Mun S. Ho, *The Quality of the U.S. Work Force, 1948–95*, Kennedy School of Government, Harvard University (February 1999), http://www.hks.harvard.edu/m-rcbg/ptep/laborjbes.pdf; Daniel Aaronson and Daniel Sullivan, "Growth in Worker Quality," Federal Reserve Bank of Chicago, *Economic Perspectives* (Fourth Quarter 2001): 53–74, http://qa.chicagofed.org/digital_assets/publications/economic_perspectives/2001/4qepart5.pdf. Goldin and Katz found that rising labor quality due to increased schooling boosted the effective size of the work force by 0.48 percent per year during 1915—2005. Aaronson and Sullivan looked at the combined effects of education, experience levels, and gender composition and found that labor quality rose by 0.33 percent per year during 1964—2000.

19. See James J. Heckman and Paul A. LaFontaine, "The American High School Graduation Rate: Trends and Levels," *Review of Economics and Statistics* 92 no. 2 (May 2010): 244–62, http://www.mitpressjournals.org/doi/abs/10.1162/rest.2010.12366?journalCode=rest; Dionissi Aliprantis, Timothy Dunne, and Kyle Fee, "The Growing Difference in College Attainment between Women and Men," Federal Reserve Bank of Cleveland, Economic Commentary no. 2011-21 (October 18, 2011), http://www.clevelandfed.org/research/commentary/2011/2011-21.pdf.

20. More recent data show an encouraging acceleration in college completion over the past few years. See Catherine Rampell, "Data Reveal a Rise in College Degrees Among Americans," *New York Times*, June 12, 2013. What remains to be seen is whether the upturn in college completion represents a durable trend or is merely a temporary response to the current weak job market.

21. Goldin and Katz, pp. 32, 39, Tables 1.2 and 1.3.

22. Dale W. Jorgenson, Mun S. Ho, and Jon D. Samuels, *Economic Growth in the Information Age: A Prototype Industry-Level Production Account for the United States, 1947–2010*, prepared for presentation at the National Bureau of Economic Research/Conference on Research in Income and Wealth, July 15–16, 2013. Both educational attainment and years of work experience have a clear connection to skill levels, but it should be noted that market remuneration—and thus, by inference, skill levels—varies with a host of other demographic factors including sex, marital status, and ethnicity. In his work assessing the financial future of Social Security, Jagadeesh Gokhale has estimated the impact of projected changes in labor composition and concluded that effective labor inputs (the product of labor quantity and quality) will actually decline over the course of the 21st century. See Jagadeesh Gokhale, *Social Security: A Fresh Look at Policy Alternatives* (Chicago: University of Chicago Press, 2010), pp. 98–99. This conclusion, however, assumes both that pay differentials along various demographic lines reflect underlying differences in skill levels and that those pay differentials will remain stable over time. Although both assumptions can be questioned, it is nonetheless sobering

to reflect on the bleak implications for long-run labor productivity should, in particular, the relative economic performance of African-Americans and Hispanics fail to improve over time.

23. See Andrew Weiss, "Human Capital vs. Signalling Explanations of Wages," *Journal of Economic Perspectives* 9, no. 4 (Fall 1995): 133–54.

24. See David A. Jaeger and Marianne E. Page, "Degrees Matter: New Evidence on Sheepskin Effects in the Returns to Education," *Review of Economics and Statistics* 78, no. 4 (November 1996): 733–40.

25. See Stephen J. Ceci and Wendy M. Williams, "Schooling, Intelligence, and Income," *American Psychologist* 52, no. 10 (October 1997): 1051–58.

26. See Enrico Moretti, "Estimating the Social Return to Higher Education: Evidence from Longitudinal and Repeated Cross-Sectional Data," *Journal of Econometrics* 121, no. 1–2 (2004): 175–212.

27. Even if schooling adds nothing to human capital, it could still generate some social return by sorting prospective workers into ability groups and thereby improving the matching of workers and jobs. See, for example, Joseph Stiglitz, "The Theory of 'Screening,' Education, and the Distribution of Income," *American Economic Review* 65, no. 3 (June 1975): 283–300.

28. See Jess Benhabib and Mark M. Spiegel, "The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data," *Journal of Monetary Economics* 34, no. 2 (October 1994): 143–73; and Lant Pritchett, "Where Has All the Education Gone?" *World Bank Economic Review* 15, no. 3 (2001): 367–91.

29. See Alan B. Krueger and Mikael Lindahl, "Education for Growth: Why and For Whom?" *Journal of Economic Literature* 39 (December 2001): 1101–36.

30. Daniel Cohen and Marcelo Soto, "Growth and Human Capital: Good Data, Good Results," *Journal of Economic Growth* 12, no. 1 (March 2007): 51–76.

31. Daron Acemoglu and Joshua Angrist, "How Large Are Human-Capital Externalities? Evidence from Compulsory Schooling Laws," *National Bureau of Economic Research Macroeconomics Annual 2000*, vol. 15 (2001): 9–74.

32. For data from 1900, see U.S. Census Bureau, *Statistical History of the United States*, Series D-182-185. For data from 2000, see U.S. Census Bureau, *2001 Statistical Abstract*, Table 593, http://www.census.gov/prod/2002pubs/01statab/labor.pdf.

33. Figures are based on Bureau of Economic Analysis data.

34. In particular, it should be noted that TFP is generally calculated for the nonfarm business sector as opposed to the economy as a whole. In other words, no attempt is made to track productivity growth (or negative growth) for the sizable fraction of economic activity undertaken by government.

35. Moses Abramovitz, "Resource and Output Trends in the United States Since 1870," National Bureau of Economic Research Occasional Paper 52 (1956), pp. 1–23.

36. The phrase "one big wave" comes from economist Robert Gordon, who argues it reflects the exploitation of major inventions from the late 19th and early 20th centuries. He is pessimistic about future prospects for TFP growth because he does not believe that the current information technology revolution has the same productive potential as those major breakthroughs of yesteryear. See Robert J. Gordon, "U.S. Economic Growth Since 1870: One Big Wave?" *American Economic Review* 89, no. 2 (May 1999): 123–28; and "Interpreting the 'One Big Wave' in U.S. Long-Term Productivity Growth," in *Productivity, Technology, and Economic Growth*, ed. Bart van Ark, Simon Kuipers, and Gerard Kuper (Boston: Kluwer Academic Publishers, 2000), pp. 19–65.

37. Data for 1871–1950 are from Gordon, "U.S. Economic Growth Since 1870: One Big Wave?" Data for 1950–2011 are from Bureau of Labor Statistics, *MFP Tables: Historical Multifactor Productivity Measures (SIC 1948–87 linked to NAICS 1987–2011)*, http://www.bls.gov/mfp/.

38. See, for example, Martin Neil Baily and Robert J. Gordon, "The Productivity Slowdown, Measurement Issues, and the Explosion of Computer Power," *Brookings Papers on Economic Activity 1988:2* (Washington: Brookings Institution, 1988), pp. 347–431; Edward F. Denison, *Trends in American Economic Growth, 1929–1982* (Washington: Brookings Institution, 1985), pp. 56–57.

39. See Gordon, "Interpreting the 'One Big Wave' in U.S. Long-Term Productivity Growth."

40. See Dale W. Jorgenson, Mun S. Ho, and Kevin Stiroh, "A Retrospective Look at the U.S. Productivity Growth Resurgence," *Journal of Economic Perspectives* 22, no. 1 (Winter 2008): 3–24; Erik Brynjolfsson and Adam Saunders, *Wired for Innovation* (Cambridge, MA: MIT Press, 2010), pp. 41–49.

41. See Cowen, *The Great Stagnation*, pp. 82–83.

42. Moore's Law refers to the long-running trend in which the number of transistors on an integrated circuit doubles roughly every two years.

43. David M. Byrne, Stephen D. Oliner, and Daniel E. Sichel, "Is the Information Technology Revolution Over?" *International Productivity Monitor* 25 (Spring 2013).

44. STEM data come from Mark Regets and B. Lindsay Lowell, *A Half-century Snapshot of the STEM Workforce, 1950–2000* (Washington: Commission on Professionals in Science and Technology, 2006). TFP data come from Bureau of Labor Statistics, *MFP Tables: Historical multifactor productivity measures (SIC 1948–87 linked to NAICS 1987–2011)*, http://www.bls.gov/mfp/.

45. See Paul S. Segerstrom, "Endogenous Growth Without Scale Effects," *American Economic Review* 88, no. 5 (December 1998): 1290–1310. Noting steadily increasing research and development (R&D) effort combined with relatively constant patent rates and no upward trend in growth rates, Segerstrom concludes that R&D is getting progressively more difficult over time.

46. Based on data from Angus Maddison, http://www.ggdc.net/maddison/oriindex.htm.

47. See Robert J. Gordon, "Revisiting U.S. Productivity Growth over the Past Century with a View of the Future," National Bureau of Economic Research Working Paper 15834 (March 2010); Jorgenson, Ho, and Samuels, "Economic Growth in the Information Age"; John Fernald, *Productivity and Potential Output before, during, and after the Great Recession*, Federal Reserve Bank of San Francisco Working Paper 2012–18 (September 2012); Congressional Budget Office, *The Budget and Economic Outlook: Fiscal Years 2013–2023* (February 2013), https://www.cbo.gov/publication/43907; and *Minutes of the Federal Open Market Committee* (June 18–19, 2013), http://www.federalreserve.gov/newsevents/press/monetary/20130710a.htm.

48. See Kevin Kelly, "The New Socialism: Global Collectivist Society Is Coming Online," *Wired*, May 22, 2009, http://www.wired.com/culture/culturereviews/magazine/17-06/nep_newsocialism?currentPage=all. Note that Kelly is using "socialism" and "collectivist" to describe purely voluntary collaboration. See also Clay Shirky, *The Cognitive Surplus: How Technology Makes Consumers into Collaborators* (New York: Penguin, 2010).

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