

THE HAMILTON PROJECT

A Dozen Economic Facts About Innovation

Michael Greenstone and Adam Looney



MISSION STATEMENT

The Hamilton Project seeks to advance America's promise of opportunity, prosperity, and growth. The Project's economic strategy reflects a judgment that long-term prosperity is best achieved by fostering economic growth and broad participation in that growth, by enhancing individual economic security, and by embracing a role for effective government in making needed public investments. We believe that today's increasingly competitive global economy requires public policy ideas commensurate with the challenges of the 21st century. Our strategy calls for combining increased public investments in key growth-enhancing areas, a secure social safety net, and fiscal discipline. In that framework, the Project puts forward innovative proposals from leading economic thinkers — based on credible evidence and experience, not ideology or doctrine — to introduce new and effective policy options into the national debate.

The Project is named after Alexander Hamilton, the nation's first treasury secretary, who laid the foundation for the modern American economy. Consistent with the guiding principles of the Project, Hamilton stood for sound fiscal policy, believed that broad-based opportunity for advancement would drive American economic growth, and recognized that “prudent aids and encouragements on the part of government” are necessary to enhance and guide market forces.



A Dozen Economic Facts About Innovation

Michael Greenstone and Adam Looney

Introduction

During the past century, innovation in mechanics, computing technology, medicine, and business practices has driven economic growth, raised wages, and helped Americans lead longer and healthier lives. The development of assembly line production, for example, and its application to the mass production of automobiles reduced the time to produce the Model T Ford by 68 percent over six years and reduced its cost by 62 percent, allowing middle-class families to afford what had once been a luxury (Williams, Haslam, and William 1992). The rapid pace of innovation and increases in productivity continued for most of the century, expanding the efficiency of American workers and providing more valuable goods and services at lower prices.

Since the 1970s, however, the pace of innovation has slowed, leading to lower overall wage growth for American workers. Moreover, those gains that have been made have not been shared equally across society. Although average wages have risen, buoyed by strong gains at the top of the distribution, the wages of many Americans have stagnated or fallen after adjusting for the cost of living over the past forty years. Reinvigorating the momentum of innovation that benefits all Americans is imperative to create broad-based economic growth and higher living standards.

To take on this challenge, The Hamilton Project held a forum, “PhDs, Policies, and Patents: Innovation and America’s Future,” on June 28, 2011. The discussion explored the evolving role of innovation in driving broad-based economic growth in the United States and the policy environment necessary to foster new ideas in science, technology, and business. From that conference The Hamilton Project pulled from the statements of each of our panelists to identify a dozen facts about innovation. These dozen facts encapsulate three themes: First, innovation has historically improved America’s overall standard of living through higher wages, lower prices, and health advancements. Second, the pace of innovation has slowed more recently and the gains from innovation have not benefitted all Americans. Third, in today’s increasingly competitive global economy, current U.S. policies are not doing enough to promote innovation. Without purposeful policies and necessary investments to spur innovation, the United States may not experience the same sort of economic and technological advances in the current century that we enjoyed in the past.

The Benefits of Innovation. Innovation is the process of discovering new ideas and realizing those ideas at large scale, changing the ways we live and work. Innovation has transformed the American economy through the development of automobiles and highways, airplanes, telecommunications, and the internet, all of which have made it progressively easier for businesses to market their products globally and connect their best workers to one another. Innovations like these drive economic growth by helping businesses produce more with less—progress that is measured as rising productivity. As businesses and workers become more productive, the prices of goods and services fall and workers' wages rise, improving our standard of living.

The first five facts in this policy memo help illustrate the benefits of innovation, starting with a look at the central role innovation has played in driving economic growth and raising average wages (Fact 1). The next four facts illustrate striking advances in medicine, business, and technology that have broadly benefited the American people. Public health advances and the development of vaccines and antibiotics have contributed to increases in life expectancy (Fact 2). Computing and telecommunications technology have made personal computers and mobile phones available to almost the entire population (Fact 3). More mundane organizational changes and behind-the-scenes improvements in management and procurement have allowed businesses to cut waste and deliver cheaper products to consumers (Fact 4). Innovations in the home, such as sophisticated household appliances that make housework faster and easier, have allowed Americans to enjoy more leisure time (Fact 5).

The Slowing Pace of Innovation. In the 1970s, the pace of innovation slowed and average wage growth followed suit. Fact 6 demonstrates how economic growth from innovation is measured and illustrates the lost income from the slowdown in innovation.

Beyond slowing average wage and productivity growth, the gains have not benefited all workers equally. Fact 7 demonstrates that the man in the middle of the earnings distribution or the median man now earns about 28 percent less than his counterpart forty years ago. (Mean or average earnings increased, even in the face of the decline in wages at the median, due to the sharp increases in earnings at the top of the income distribution.) Education, in particular, is a key factor behind stagnant wages and declining earnings. A college graduate now earns about double what an individual with only a high-school diploma earns, but rates of educational attainment among men have been flat for thirty years. In

contrast, women have seen earnings increase, in part because of rising educational attainment.

What Is the Future of U.S. Innovation? Government policies can help reignite the engine of productivity growth by creating a fertile environment for innovation. One component of such an environment is a regulatory framework that does not unnecessarily burden businesses and creative entrepreneurs (Fact 8).

At the same time that productivity growth has slowed, the United States' investments in many productivity-enhancing areas are lagging. Federal research and development (R&D) as a percent of GDP has declined from an average of 1.2 percent in the 1970s to 0.7 percent in the 2000s (Fact 9). Government funding for R&D is critical because the private sector may lack incentives to engage in the basic research that plays a critical role in productivity growth.

Nor is the United States producing enough talent in science, technology, engineering, and math (STEM) fields that are critical to innovation. Among OECD countries, the United States has one of the lowest shares of degrees awarded in STEM fields (Fact 10). Women are starting STEM majors in undergraduate studies, but are less likely to continue into graduate study than are their male counterparts (Fact 11). Recently, high-skill immigrants have pursued careers in these fields at high rates at American colleges and universities. More than 40 percent of STEM PhDs were awarded to foreign-born students (Fact 12). Without appropriate immigration policies, more and more highly educated foreign students may leave the United States after studying here—taking their skills with them.

Achieving robust and broad-based economic growth requires effective government policies, and these policies often involve making difficult political choices that involve reprioritizing expenditures toward policies that promote future prosperity. The alternative is slowing productivity gains and uneven growth that leaves many families behind and undermines the core of the American Dream that each generation will have an opportunity to do better than the previous one. Recognizing the importance of such policies, The Hamilton Project has offered proposals to fund more fellowships for students pursuing degrees in science and engineering, expand the use of prizes for scientific discoveries, and streamline the process of obtaining patents. Drawing from this previous work and the 2011 forum, The Hamilton Project will continue to seek out policy ideas to increase innovation, economic growth, and broad participation in that growth.

1. Innovation drives economic growth and raises wages.

America has long had a culture and an economic system that has spurred innovation and scientific advance that in turn created vast new industries, enormous numbers of jobs, and a powerful competitive position in the global economy.

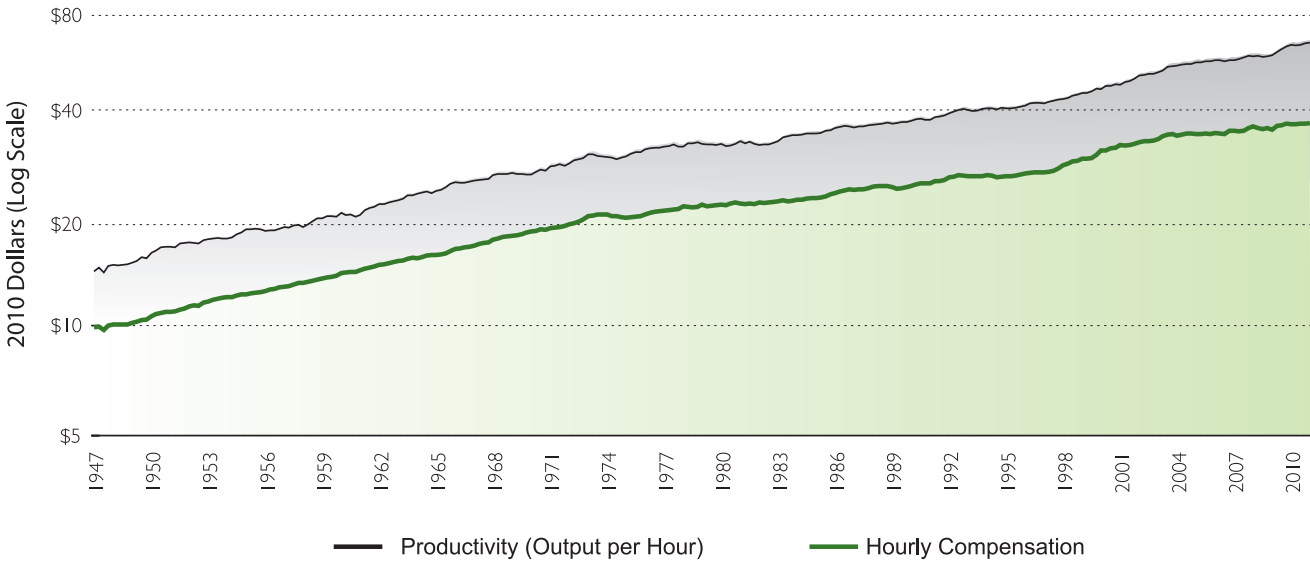
—Robert E. Rubin, Co-Chair, Council on Foreign Relations and Former U.S. Treasury Secretary

When workers can produce more, they earn more. In the latter half of the past century, labor productivity and hourly compensation (wages and benefits) increased at a rate of about

2 percent per year. Real hourly compensation increased from an average \$9.88 per hour in 1947 to \$35.44 per hour today. These improvements in compensation and the rising living standards they afford reflect innovations that have made businesses and people more productive.

Although average compensation increases follow productivity growth, the wage gains need not be equal across the population. As is discussed in more detail in Fact 7, earlier gains from innovation benefitted Americans broadly. However more recently, wage increases have been concentrated at the top and many Americans have experienced wage declines.

FIGURE 1. Productivity and Hourly Compensation



Note: Hourly compensation adjusted for inflation using the non-farm business implicit price deflator. Source: Bureau of Labor Statistics.

I. The Benefits of Innovation

2. Innovation improves U.S. life expectancy.

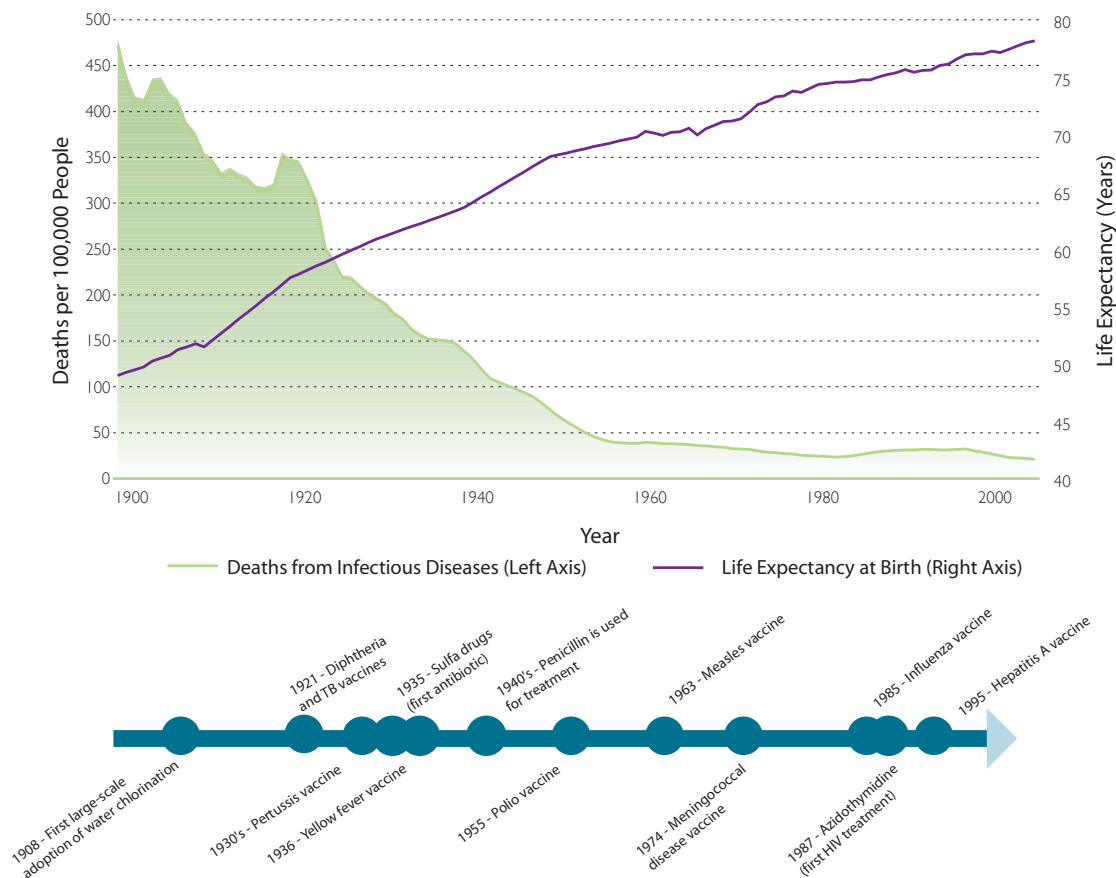
Longevity has improved by about one year every six years in this country . . . if you add up what that's contributed to the economy since 1970, that's estimated to be worth about \$95 trillion.

—Francis S. Collins, Director, National Institutes of Health

In 1920, average life expectancy in the United States was only fifty-eight years. By 1960 it had jumped to seventy years and today it is seventy-nine years. These rapid increases in life expectancy were brought about by medical innovations and improvements in public health practices. One example of how innovation improves longevity is the steep drop in mortality from infectious and bacterial diseases.

Technological improvements, such as filtration and chlorination of water in cities significantly contributed to mortality reductions in the earlier half the twentieth century. According to some estimates, cleaner water accounted for nearly half of the mortality reduction in American cities from 1900 to 1936 and produced health benefits for Americans twenty-three times higher than the costs of the investments (Cutler and Miller 2005). Reductions in the incidence of mortality from infectious diseases were also brought about by the development and dissemination of vaccines and antibiotics, such as penicillin (CDC 1999).

FIGURE 2.
Deaths from Major Infectious Diseases



Note: Deaths from infectious diseases are represented by the five-year moving average of mortality per 100,000 people.
Source: National Center for Health Statistics and World Bank.

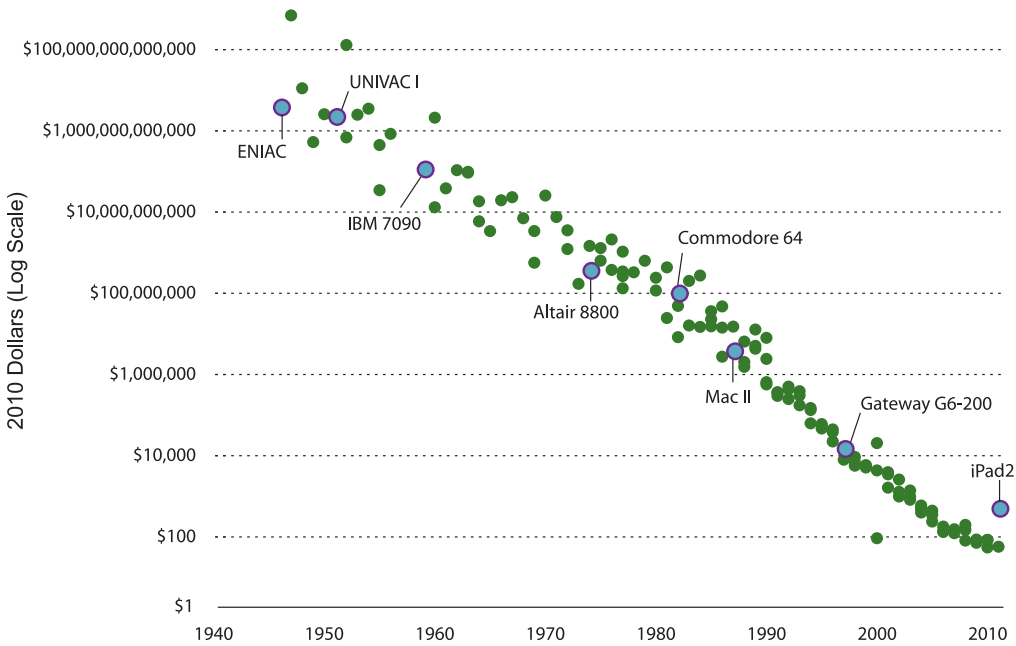
3. Innovation makes technology affordable.

Most people don't think about disk drives but they store, search, and retrieve almost limitless amounts of information today and now, with cloud computing, can be accessed wirelessly. I used to say that you have now the Library of Congress on your computer. Now you have the ability to access almost all the world's information in your pocket.

—Glenn Hutchins, Co-Founder and Co-Chief Executive, Silver Lake

Consumer technologies like personal computers and mobile devices make all of our lives easier, allowing us to quickly connect with people across the world and retrieve information regardless of our location. The price of these technologies has decreased rapidly, even more so than the sticker price would indicate, because new computers are so much more powerful than older iterations. The latest computer may be more expensive than the previous model but relative to what the computer has to offer, the cost is lower. If the typical worker in 1982 wanted to purchase something with computing power of an iPad2, it would have cost more than the 360 years worth of wages.

FIGURE 3.
Cost of Computing Power Equal to an iPad 2



Note: The iPad2 has computing power equal to 1600 million instructions per second (MIPS). Each data point represents the cost of 1600 MIPS of computing power based on the power and price of a specific computing device released that year.
Source: Moravec n.d..

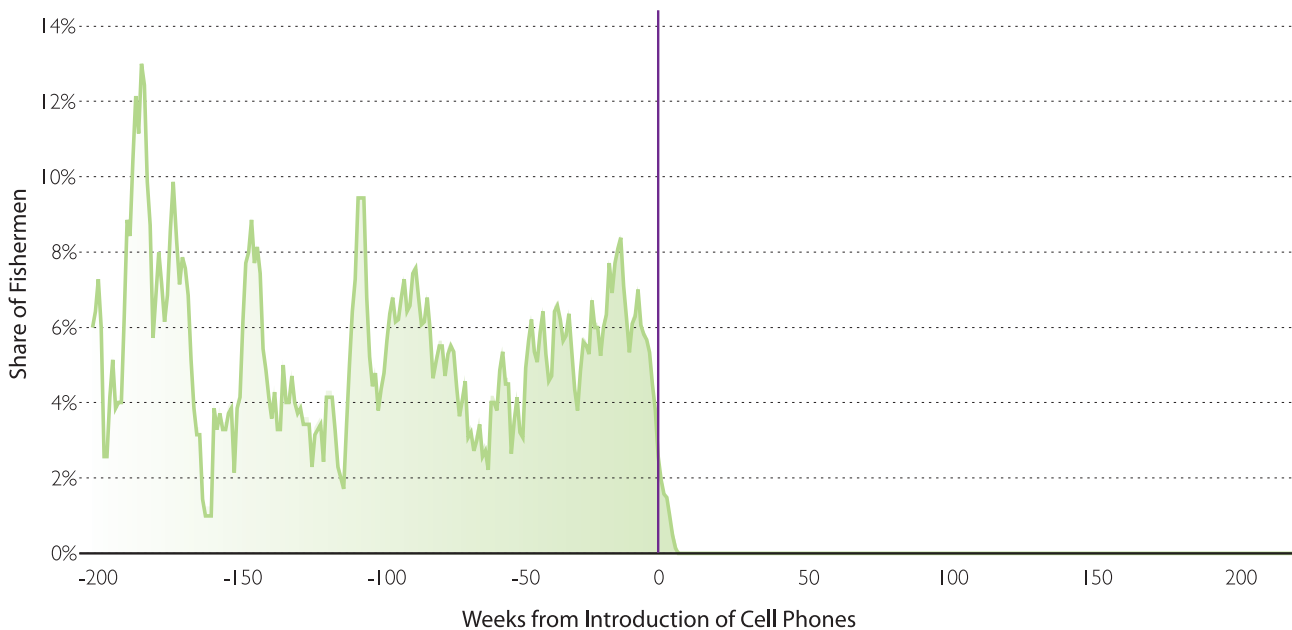
I. The Benefits of Innovation

Farmers [in developing countries] are using cell phones to text message their water sprinklers miles down the road to turn on and off. And they're becoming a lot more productive with pricing transparency, taking advantage of inefficiencies and arbitrage in the market. . . . They're harnessing the power of technology to improve their lives and work.

—Aneesh Chopra, Assistant to the President and Chief Technology Officer of the United States

In both industrialized nations and emerging markets, technology can revolutionize business and improve markets. To give one salient example, between 1998 and 2002, mobile phones were introduced to the coast of southern India. Before the introduction of mobile phones, fishermen would take their catch to their local market, where sometimes there were few customers or too much competition, and fish would go to waste. On average, about 7 percent of the fishermen reported waste, and on some days almost 24 percent of fishermen lost money on wasted fish. When cell phones were introduced, fishermen could find out what the price was in different markets, and take their fish to markets with higher demand. The result was the complete elimination of wasted fish (Jensen 2007).

FIGURE 4.
Share of Fishermen with Wasted Fish



Note: Share of fishermen is a seven week moving average.
Source: Jensen 2007.

4. New organizational structures lead to rising standards of living.

We've had a tendency in this conversation to equate innovation with science and technology. . . . The hard parts about Facebook are not about writing the computer program that connects the people together. That's not the hard part about Amazon either. Retail if you think about it, has experienced very profound innovation, but not the kind of innovation that comes from a laboratory.

—Lawrence H. Summers, Charles W. Eliot University Professor, Harvard University and Former U.S. Treasury Secretary

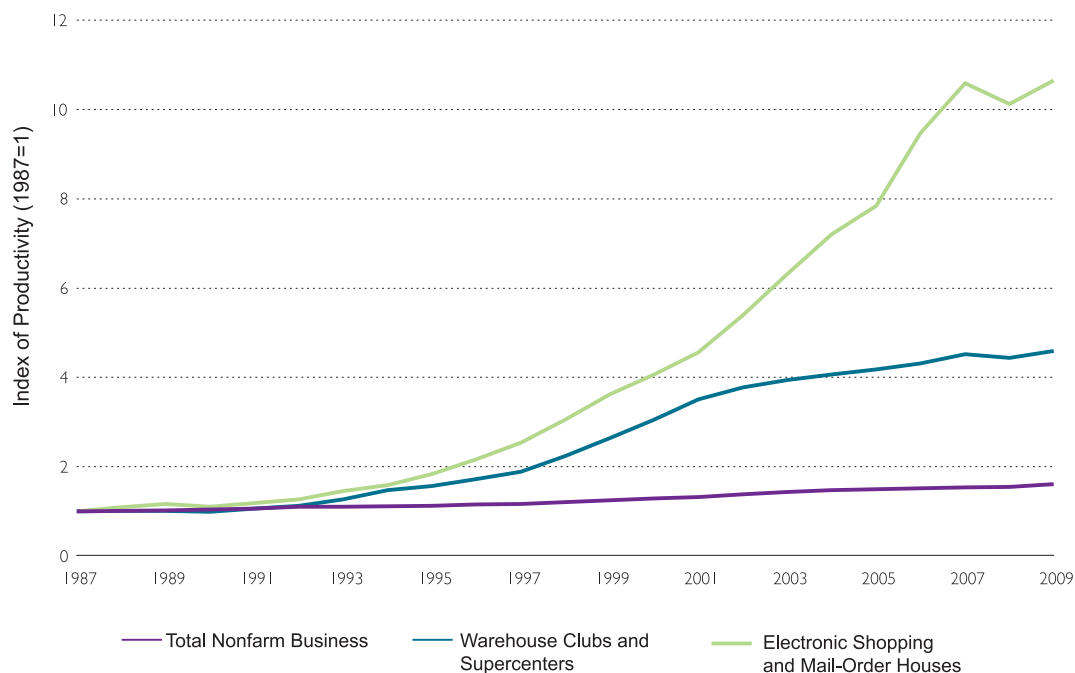
The innovations that improve our daily lives are not just new inventions or technological discoveries. They also include ideas about how to reorganize businesses to make them more productive and efficient. In the last twenty years, organizational innovations—from big box retailers to internet

sales—have allowed retailers to streamline their internet sellers supply chain, delivering more output with less work.

Labor productivity at warehouse clubs and supercenters has more than quadrupled since 1987, while labor productivity for the nonfarm economy as a whole increased by only 60 percent. Similarly, electronic shopping and mail order retailers have increased productivity more than 10-fold. It is therefore not surprising that the share of retail sales going to the big box retailers and internet sales has risen from 3 percent in 1992 to 16.5 percent in 2010.

Consumers have benefited from these productivity improvements through lower prices at stores such as Costco and Target, or when shopping online at Amazon or Zappos, to name just a few examples. Competition from the new brand of supercenters and online retailers also drove down the prices of products at other local stores. These lower prices have disproportionately benefited low-income families, who tend to spend a larger fraction of their income on food and other basic necessities (Hausman and Leibtag 2005).

FIGURE 5.
Labor Productivity Growth



Note: Warehouse clubs and supercenters are defined as stores retailing a general line of groceries in combination with general lines of other products.

Source: BLS.

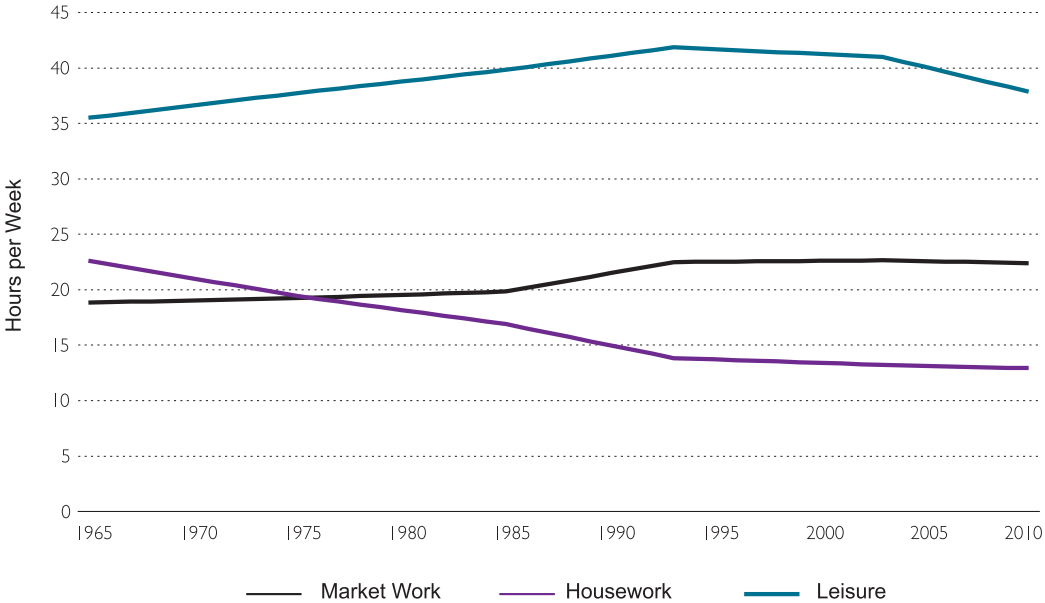
5. New household technologies allow more time for family and leisure.

In the 1960s and 1970s household appliances such as microwaves, dishwashers, and clothes dryers were developed and became commonplace. The clothes dryer, first marketed in the early 1950s, was in 50 percent of all households by the early 1970s (Bowden and Offer 1994). The development of household appliances made it easier to complete household chores such as preparing meals and doing laundry. As this sort of work was predominantly done by women, the number of hours spent on household work by women declined substantially. Compared to 1965, women spent 9.7 fewer hours per week doing housework, amounting to 12.9 hours per week in 2010. Men's time spent doing housework actually increased slightly—by 2.3 hours per week—totaling 4.2 hours per week.

With less time going to household work, more time is spent on leisure. Leisure increases also come about because of rising wages; as basic needs are met, individuals are more likely to choose leisure over work.

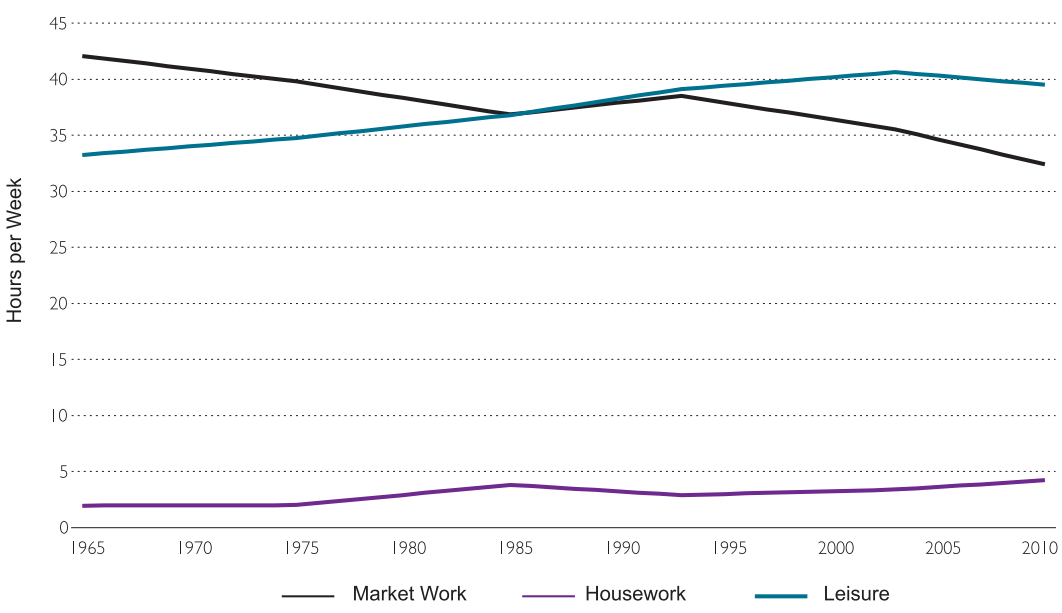
Incorporated into the definition of leisure is time spent caring for children. The time devoted to childcare has risen for both men and women. A narrower definition of leisure that excludes childcare has also increased for both men and women.

FIGURE 6A.
Time Spent on Work and Leisure Activities by Women



Note: Market work is any work for pay. Housework is a measure of total time spent on core non-market work such as cooking and cleaning. Leisure is the total time spent on all principle leisure including child care, socializing, and passive and active leisure activities.
Source: Aguiar & Hurst 2007, Table II and Table III; ATUS 2010.

FIGURE 6B.
Time Spent on Work and Leisure Activities by Men



Note: Market work is any work for pay. Housework is a measure of total time spent on core non-market work such as cooking and cleaning. Leisure is the total time spent on all principle leisure including child care, socializing, and passive and active leisure activities.
Source: Aguiar & Hurst 2007, Table II and Table III; ATUS 2010.

II. The Slowing Pace of Innovation

6. The pace of American innovation has slowed during the past four decades.

If we look at measures of what economists call total factor productivity, growth has mostly been low since 1973. That is, we are innovating at a slower pace. We're relying more on people to work longer hours to get more output.

—Tyler Cowen, Professor of Economics, George Mason University

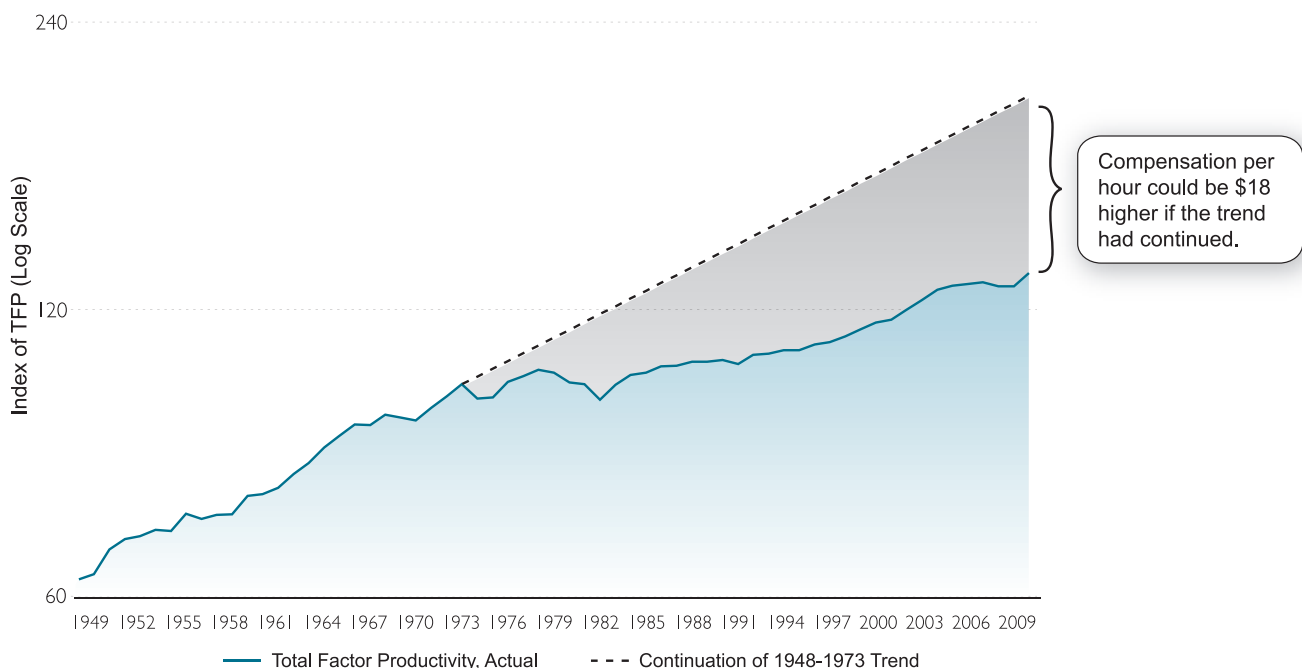
Innovation contributes to economic growth as businesses use new technologies and ideas to produce more with fewer resources. The economic growth not accounted for by known factors such as increases in the number of machines, labor, or a more educated workforce is called total factor productivity (TFP) growth. TFP thus measures any advancement that has been made in how to use existing resources to increase overall output and incomes. Those advancements can be

technological, as is the case with the internet, which helps people accomplish tasks faster, medical, because healthier people are better workers, or organizational changes that help businesses produce more such as the assembly line.

Since 1973 the pace of innovation, as measured by TFP growth, has slowed. Prior to 1973, TFP increased at an annual rate of 1.9 percent, but since then this growth rate has fallen to 0.7 percent. If TFP had continued growing at the pre-1973 trend and that productivity gain were reflected in workers' compensation, compensation could be 51 percent higher, or about \$18 per hour more than today's average of \$35.44 per hour. This calculation highlights that small changes in innovation and annual TFP growth lead to large differences in long-run standards of living.

FIGURE 7.

Total Factor Productivity



7. Innovation has failed to increase wages for a substantial number of Americans.

Over the past 40 years, a period in which U.S. GDP per capita more than doubled, the annual earnings of the typical man have actually fallen. One reason behind this is education: men have not responded to the clarion call to enhance their credentials and skills.

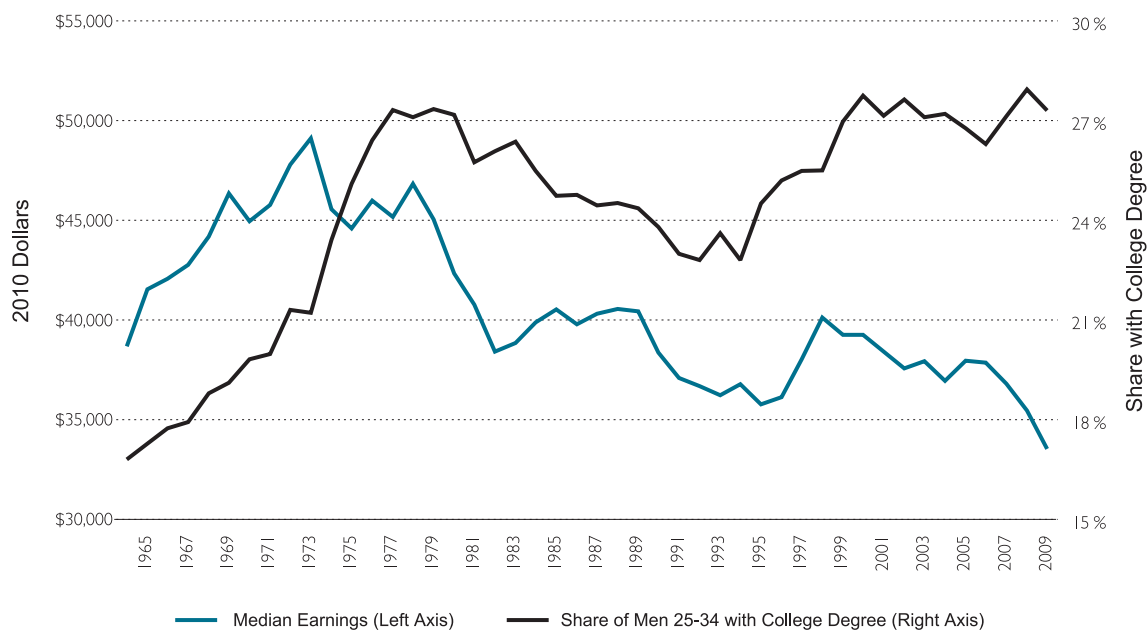
—Michael Greenstone, Director, The Hamilton Project

Average earnings growth tracks the growth of labor productivity, as Fact 1 illustrates. One implication of slowing productivity growth is that average earnings growth has slowed too. But for many Americans, the story is not just one of slowing gains but of outright declines in earnings, because increases in average wage growth have not been widely shared. Earnings for men in the middle of the income distribution have actually declined by around 28 percent since 1969 because of stagnating wages for those men that do work and because of declining employment rates.

Stagnating wages and declining employment opportunities for men are in part due to a failure to increase educational attainment. The market has signaled that education is extremely valuable: college graduates have roughly double the earnings of high school graduates. Indeed, even after accounting for the full costs of college attendance, the internal rate of return to completing a bachelor's degree is 15.2 percent and exceeds other standard investments. The share of women receiving bachelor's degrees has been on the rise but the rate of bachelor degree receipt among men has stagnated. In the late 1970s, about 27 percent of men aged twenty-five to thirty-four had graduated from college; since then, the share fell through the 1980s and has only recently approached the level it was thirty years ago.

Women have seen greater earnings increases than men because of rising rates of educational attainment and labor force participation, the entry of female workers to higher-paying professions, and longer work hours. In the past decade, however, wages of women have begun to stagnate as well.

FIGURE 8.
Median Earnings and Educational Attainment of Men



Note: Median earnings of all men ages 25-64. Source: IPUMS-CPS and IPUMS-USA.

III. What Is The Future of U.S. Innovation?

8. Significant barriers to innovation exist in the government and the private sector.

There's a clear recognition that innovation can be compromised if rules are redundant, inconsistent, or overlapping. And if you want to free up the private sector to innovate, we need to get that problem under control.

—Cass Sunstein, Administrator, Office of Information and Regulatory Affairs, U.S. Office of Management and Budget

Effective government is important for fostering innovation. One role of the government is the approval of patents, which encourages innovation by allowing individuals to profit from their ideas. The time for approval of patents has nearly doubled since 1990, rising from 18.3 months to 35.3 months in 2010.

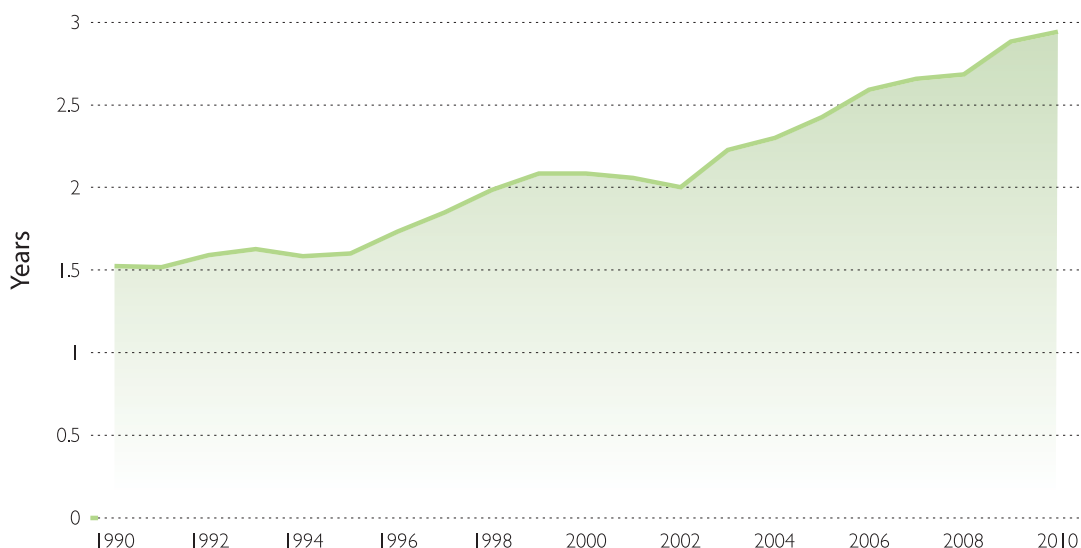
Governments also need to establish a regulatory environment that reduces uncertainty for innovators and that reduces barriers to innovation. Regulations exist to protect the health and welfare of us all, but those benefits must be weighed against the costs to consumers and businesses of complying with those rules.

Work changes not at the pace of the new enabling technologies that enter it but at the pace that organizations change to take them up. And that's slower. It's slower to change bureaucracies around.

—Tim Bresnahan, Professor of Technology and the Economy, Stanford University

Barriers to innovation also exist within the private sector. Sometimes great ideas can be stymied by organizations that are resistant to change, and it is often the case that technologies are developed for which there is no existing infrastructure. Many businesses have not yet figured out how tools such as the iPad or social networking programs like Facebook can be used to make workers more productive; nor have many figured out how to use many emerging health technologies so that benefits exceed costs.

FIGURE 9.
Average Wait Time on Patent Applications



Note: Average wait time on patent applications reflects the time lag between the application for a patent and its approval.
Source: U.S. Patent and Trademark Office.

9. Federal support for research & development has declined in recent years.

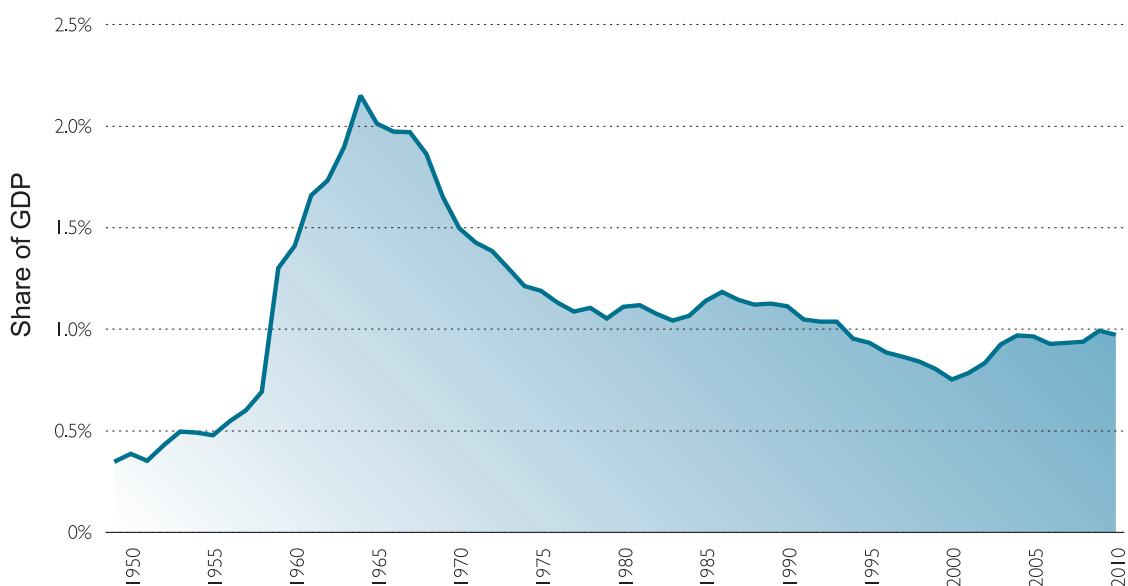
I'm sure we are missing out on opportunities that could be supported if we were in a more favorable environment—because it's very hard to assess when you look at a proposal whether, in fact, this is going to be a successful new innovation. Sometimes it's the wacky science that you most don't want to miss supporting. Yet wacky science at a time where you're only funding one out of six grants may be difficult for our peer review process to identify and say, yeah, we're going to do that—even though it means not doing some very solid, established science that's in the same pool.

—Francis S. Collins, Director, National Institutes of Health

Government investment in research and development (R&D) as a percent of GDP has declined from a high of 2.2 percent in 1964 to 1 percent today. Support of federal R&D spending is critical to U.S. innovation because government can sponsor

the kind of “basic” research projects that seek wide-ranging scientific understanding that can affect entire industries, rather than individual firms. In contrast, private sector firms tend to focus their R&D on “applied” projects, where they can capture the entire payoff. Their role is not to undertake broad R&D for the general benefit of our nation. For example, in the 1960s, the Defense Advanced Research Projects Agency sponsored efforts to develop the structure and technologies that now form the foundation of the modern internet. A team of computer scientists at the agency created revolutionary new protocols to allow computers to communicate across the country. Other products resulting from federal investments in basic research include barcodes, fiber optics, magnetic resonance imaging (MRI) machines, and GPS technology. The U.S. government has historically funded about half of all basic research, whether done within the government or at universities. Less than 5 percent of R&D performed by industries is in basic research.

FIGURE 10.
Federal Research and Development Spending



Source: OMB, Table 9.7 “Summary of Outlays for the Conduct of Research and Development: 1949–2012.”

III. What Is The Future of U.S. Innovation?

10. Relatively few U.S. college students study fields critical to innovation.

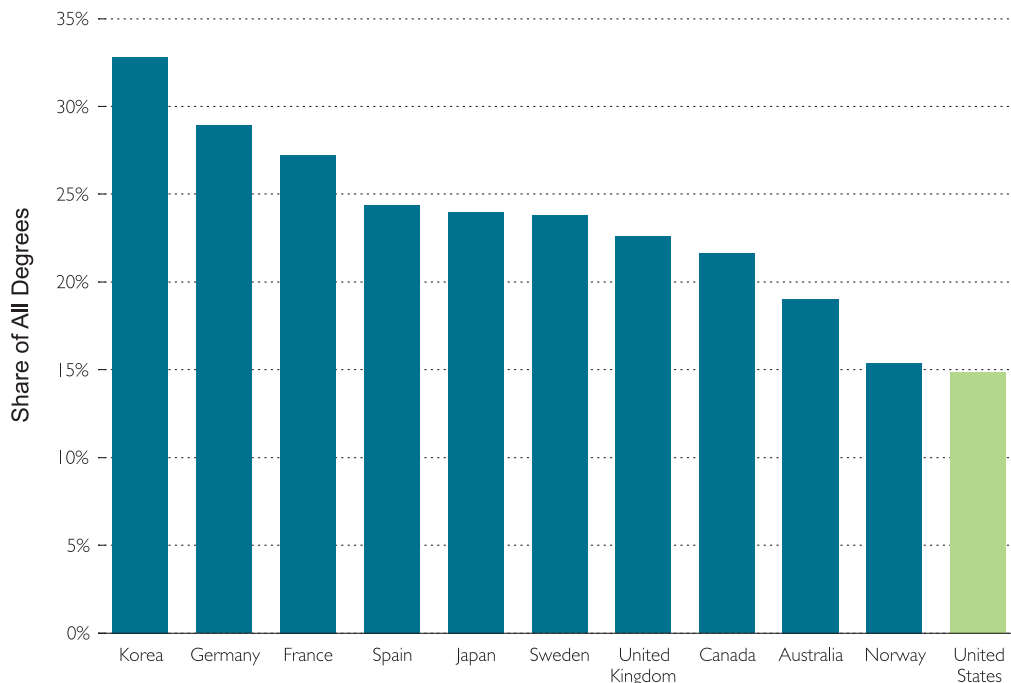
Why don't we have more advanced manufacturing in the United States? In PCAST's report on advanced manufacturing for the President, we talked to a number of companies. The most consistent reason was "We can't find the types of workers we need. . . . Getting enough factory floor engineers, not necessarily with fancy engineering degrees, but with the ability to be quantitative and increase a factory's efficiency. . . . was again and again cited as a frustration with doing business in the United States.

—Eric Lander, Co-Chair, President's Council of Advisors on Science and Technology (PCAST) and President, Broad Institute of MIT and Harvard

The United States lags behind other countries in training students in STEM fields that help advance scientific and technological progress. The share of post-secondary degrees in STEM fields is twice as high in South Korea as it is in the United States.

FIGURE 11.

Post-Secondary Degrees Conferred in Science, Technology, Engineering, and Math (STEM) Fields



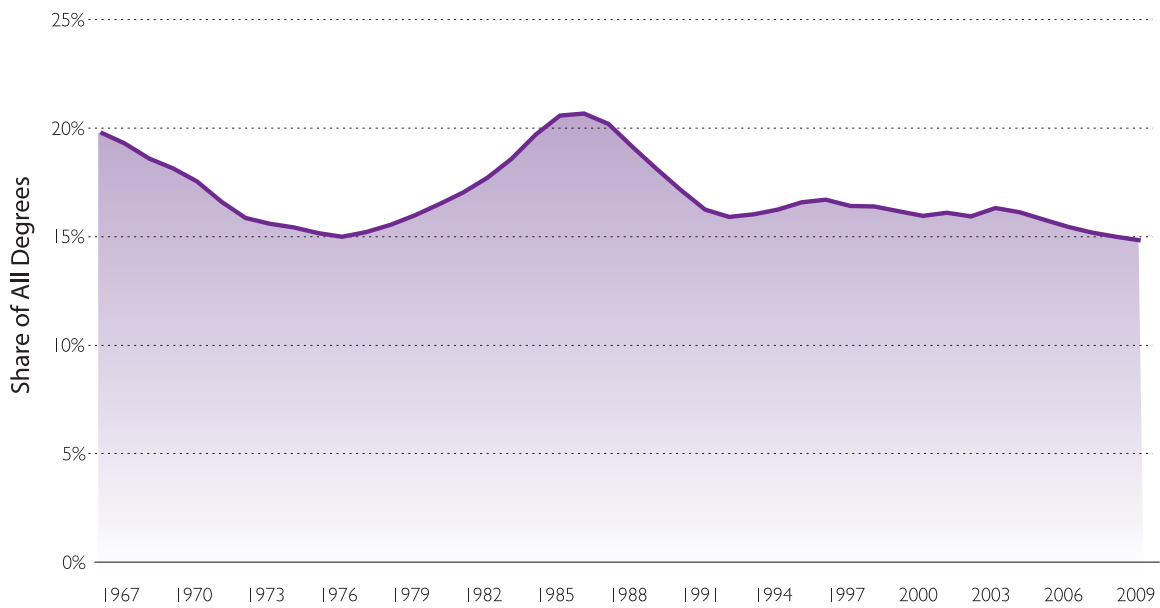
Source: Organisation for Economic Co-operation and Development 2008.

III. What Is The Future of U.S. Innovation?

The share of U.S. degrees in science, technology, engineering, and math (STEM) fields rose in the 1980s as computer science became popular, but this was a short-lived trend. In the 1990s, the share of bachelor's degrees in STEM fields leveled off and the share of advanced degrees declined. The total number of doctorates awarded in the physical sciences and science technologies actually remained constant from 1970 to 2008 despite a rising number of doctorates awarded.

FIGURE 12.

Share of U.S. Degrees Awarded in Science, Technology, Engineering, and Math (STEM) Majors



Note: Includes bachelor's degrees, master's degrees and doctorates.

Source: IPEDS Completion Survey.

III. What Is The Future of U.S. Innovation?

11. American women are less likely to continue in STEM fields than American men.

You don't target girls in high school. . . . You look to elementary school, and that can be done through mentoring and, I think, encouragement. I only have data from my own institution, but we have a lot of women in engineering, in materials science, etc. It's sometimes more women undergraduates than men. But the area that we have a problem with is getting more to go on for their PhD or getting more women to go on to academia.

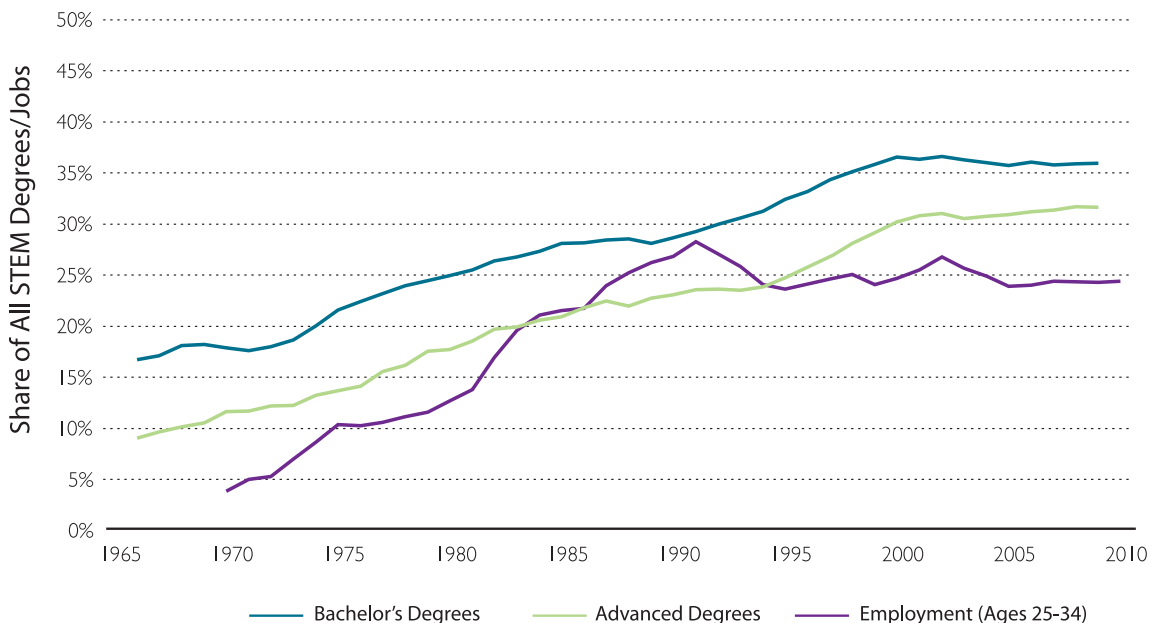
—Angela Belcher, Professor of Materials Science, Engineering and Biological Engineering, MIT

The share of science, technology, engineering, and math (STEM) degrees awarded to women was on the rise at both the undergraduate and graduate level through 2000 but then leveled off. Moreover, the two trends never converge, indicating that women's progress in STEM fields at undergraduate levels

has not been fully realized at more advanced levels. In contrast, the share of men studying STEM fields is relatively similar for both undergraduate and graduate students.

Recent employment trends show a similar pattern. Women's representation in STEM employment increased up until the 1990s along with their share of STEM graduates, but women's percent of STEM employment leveled off more quickly. Currently, women are still underrepresented in STEM employment relative to their representation in either bachelor's or advanced degree obtainment. Although there is a lag between undergraduate and graduate degree receipt, the data still suggest that there is a leaky pipeline moving women from undergraduate study in STEM to more advanced study and employment in those fields.

FIGURE 13. Science, Technology, Engineering, and Math (STEM) Degree Recipients and STEM Employees who are Women



Note: Advanced degrees include master's degrees and doctorates. Employment is a 3-year moving average. Teachers are excluded from employment numbers because subject of instruction could not be determined.

Source: IPEDS Completion Survey and IPUMS-CPS.

12. U.S. policy makes it difficult for international students to stay and work.

We've had a great opportunity in the past to recruit bright minds from all over the world. Many of them have stayed and become central to our own national success. But they are increasingly not staying. The opportunities to go back home in places like China and India are getting very strong, and our visa policies have not particularly been friendly to many of those individuals.

—Francis S. Collins, Director, National Institutes of Health

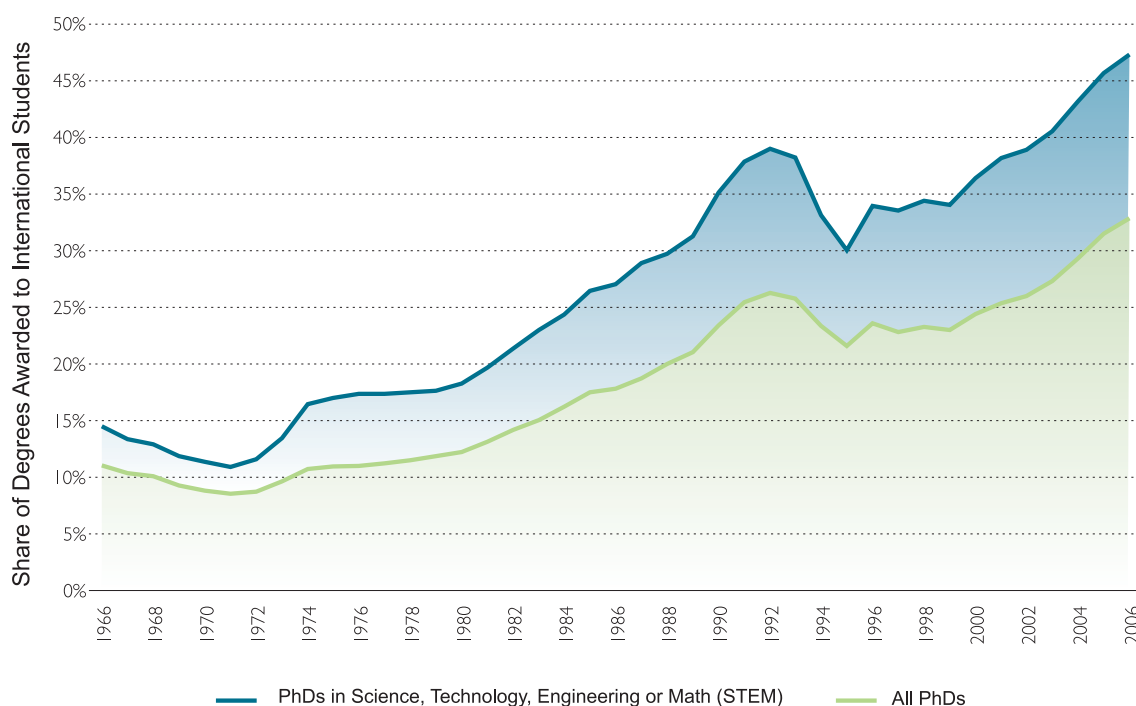
American universities are attracting more international students, and these students account for an increasingly large share of advanced degrees. In 2006, more than 30 percent of all PhDs in the United States were awarded to noncitizens. Noncitizens made up an even larger share of PhDs in science, technology, and math (STEM) fields—about 47 percent.

Moreover both the share of all PhDs going to noncitizens and the share of STEM PhDs going to noncitizens have been increasing rapidly in recent years.

Universities clearly recognize the talents of international students, but it is less clear whether our immigration policy makes it easy to integrate these students into the workforce. The Hamilton Project's previous release, "Ten Economic Facts about Immigration," further explores the benefits of immigration for our economy.

FIGURE 14.

PhDs Awarded by U.S. Universities to International Students



Note: PhDs awarded to students who are temporary residents.

Source: NSF Survey of Earned Doctorates/Doctorate Records File.

Endnotes

1. Innovation drives economic growth and rising wages.

Figure 1: Productivity and Hourly Compensation

Source: Annual hours and hourly compensation levels made available by the Bureau of Labor Statistics (BLS; n.d.); Bureau of Economic Analysis (BEA; n.d., “Table 1.3.3. Real Gross Value Added by Sector, Quantity Indexes” and “Table 1.3.5. Gross Value Added by Sector”).

Productivity is defined as real output (in 2010 dollars) in the non-farm business sector divided by total hours worked in the non-farm business sector. Real hourly compensation is adjusted using the non-farm business sector implicit price deflator.

2. Innovation improves U.S. life expectancy.

Figure 2: Deaths from Major Infectious Diseases

Source: National Center for Health Statistics (n.d.a., n.d.b.); World Bank (n.d.).

Infectious diseases are the twelve leading diseases that contributed to mortality between 1900 and 1920 for which vaccinations were later developed. These diseases are anthrax, diphtheria, measles, meningitis, pertussis, pneumonia, polio, smallpox, tetanus, tuberculosis, varicella, and yellow fever.

3. Innovation makes everyday technologies more affordable.

Figure 3: Cost of Computing Power Equal to an iPad2

Source: Moravec (n.d.).

Sample includes 137 computers produced between 1946 and 2011. Computer costs in 2010 dollars are divided by processing speeds in millions of instructions per second (MIPS) and multiplied by the processing speed of the iPad2 (1600MIPS). Nominal costs were adjusted for inflation using the CPI-U.

If the typical worker in 1982 wanted to purchase something with the computing power of an iPad2, she would have had to spend more than 360 years' worth of wages.

Source: Census Bureau (n.d.a., “Table P-43 Workers [Both Sexes Combined—All] Median and Mean Earnings: 1974 to 2009”).

Earnings in current dollars are adjusted for inflation using the CPI-U.

The computing power of an iPad2 measured in millions of instructions per second (MIPS) at the cost/MIPS of the Commodore 64 would cost approximately \$9,038,591 in 1982 in 2010 dollars. In 1982, median earnings of workers were \$24,969 in 2010 dollars. Accordingly, it would have taken approximately 360 years for the typical worker in 1982 to afford the computing power of an iPad2.

Figure 4: Share of Fishermen with Wasted Fish

Source: Jensen (2007). Data made available by the author.

Equal numbers of fishermen from three markets were sampled. For each week, the share of fishermen with wasted fish was averaged over the three villages. The graph shows a seven-week centered moving average. As a result, the maximum share of fishermen reporting wasted fish in any market in any week exceeds the highest average number shown in the chart.

4. New organizational structures lead to rising standards of living.

Figure 5: Labor Productivity Growth

Source: BLS (n.d.).

Labor productivity is defined as output divided by hours worked in each sector. Warehouse clubs and supercenters include stores that sell a general line of groceries in combination with general lines of new merchandise, such as apparel, furniture, and appliances. Electronic shopping and mail order houses include retailers that sell all types of goods using non-store means such as catalogs, toll-free telephone numbers, or electronic media. All three series have been indexed so that productivity in 1987 equals 1.

The share of retail sales going to the big box retailers and internet sales has risen from 3 percent in 1992 to 16.5 percent in 2010.

Source: Census Bureau (n.d.b.).

Market share calculated as share of total retail sales.

5. New household technologies allow more time for family and leisure.

Figure 6A: Time Spent on Work and Leisure Activities by Women

Figure 6B: Time Spent on Work and Leisure Activities by Men

Source: Aguiar and Hurst (2007, “Table II,” p. 976, and “Table III,” p. 977); BLS (2010, American Time Use Survey [ATUS]). Time use data for 1965–2003 come from Aguiar and Hurst’s alignment of five different time use surveys including (1) 1965–1966 America’s Use of Time, (2) 1975–1976 Time Use in Economics and Social Accounts, (3) 1985 Americans’ Use of Time, (4) 1992–1994 National Human Activity Pattern Survey, and (5) the 2003 American Time Use Survey. For 2004–2010, we use the Aguiar and Hurst methodology and the 2010 American Time Use Survey.

Housework is defined as food preparation, food presentation, kitchen or food cleanup, washing or drying clothes, ironing, dusting, vacuuming, indoor cleaning, indoor painting, and so on. Market work includes work for pay at all jobs but excludes commuting, work breaks, and job search activities. Leisure is defined as socializing, passive leisure, active leisure, volunteering, pet care, gardening, and all childcare activities.

6. The pace of American innovation has slowed during the past four decades.

Figure 7: Total Factor Productivity

Source: BEA (n.d., “Table 1.3.5. Gross Value Added by Sector”); BLS (n.d., “Private Business and Private Nonfarm Business Multifactor Productivity Tables”); Census Bureau (n.d.c.).

Compensation per hour could be \$18 higher if the trend had continued.

This calculation assumes that the percentage change in non-farm business output is equal to the percentage change in labor and capital inputs in the non-farm business sector plus the percentage change in TFP. The 1948–1973 TFP trend is calculated as the geometric mean of TFP growth during this period. To calculate hypothetical output growth, the percentage change in TFP is assumed to continue at the 1948–1973 trend through 2010, and other inputs are assumed to have increased at their observed rates. The resulting hypothetical output level is 51.2 percent higher in 2010. Changes in output per hour and compensation growth were closely linked over the past sixty years (see Fact 1). If the relationship between productivity and compensation had remained the same, the hypothetical 51 percent increase in productivity implies a 51 percent (\$18) increase in compensation per hour, from \$35.44 to \$53.51.

7. Innovation has failed to increase wages for a substantial number of Americans.

Figure 8: Median Earnings and Educational Attainment of Men

Source: King et al. (2010); Ruggles et al. (2010).

The data were constructed using information from the Current Population Survey (CPS) and the Census Bureau.

The CPS population universe includes only the civilian non-institutionalized population. Population counts in the CPS are adjusted to reflect the institutionalized population using the 1960, 1970, 1980, 1990, and 2000 censuses and 2006, 2007, 2008, and 2009 American Community Surveys (ACS). For years in between census and ACS survey years, we linearly interpolated the size of the institutionalized population.

Earnings are defined as the sum of wage and salary income, non-farm business income, and farm income. The sample includes all men ages twenty-five to sixty-four, including those who reported no earnings. The figure reports the median earnings of this entire sample.

The figure also presents the share of men ages twenty-five to thirty-four with a bachelor’s degree or more (from 1993 to the present) or the share reporting four years of college or more (prior to 1993).

8. Significant barriers to innovation exist in the government and the private sector.

Figure 9: Average Wait Time on Patent Applications

Source: Patent and Trademark Office (n.d.).

9. Federal support for research & development has declined in recent years.

Figure 10: Federal Research and Development Spending

Source: Office of Management and Budget (OMB; n.d., “Table 9.7, Summary of Outlays for the Conduct of Research and Development: 1949–2012”); BEA (n.d., “Table 1.1.6., Real Gross Domestic Product, Chained Dollars”).

The U.S. government has historically funded about half of all basic research, whether done within the government or at universities.

Source: National Science Foundation (NSF; 2008, “Table 6: U.S. Basic Research Expenditures, by Source of Funds and Performing Sector: 1953–2008”).

Less than 5 percent of R&D performed by industries is in basic research.

Source: NSF (2008, “Table 5: U.S. Research and Development Expenditures, by Source of Funds and Performing Sector: 1953–2008” and “Table 6: U.S. Basic Research Expenditures, by Source of Funds and Performing Sector: 1953–2008”).

10. Relatively few U.S. college students study fields critical to innovation.

Why don’t we have more advanced manufacturing in the United States? In PCAST’s report on advanced manufacturing for the President, we talked to a number of companies. The most consistent reason was “We can’t find the types of workers we need. . . . Getting enough factory floor engineers, not necessarily with

fancy engineering degrees, but with the ability to be quantitative and increase a factory's efficiency . . . was again and again cited as a frustration with doing business in the United States.

Source: President's Council of Advisors on Science and Technology (2011).

Figure 11: Post-Secondary Degrees Conferred in Science, Technology, Engineering and Math (STEM) Fields

Source: Organisation for Economic Co-operation and Development (OECD; 2008).

Percentage of degrees awarded in STEM fields was calculated by adding degrees awarded in (1) science and (2) engineering, manufacturing, and construction, and dividing by the total number of degrees awarded in tertiary Type A (bachelor's or equivalent) and advanced degree programs.

Figure 12: Share of U.S. Degrees Awarded in Science, Technology, Engineering, and Math (STEM) Majors

Source: Department of Education (n.d.).

The sample for degree completions is the NSF population of institutions. STEM degrees include awards in natural sciences, mathematics, computer science, engineering, and engineering technologies. Data were not available for 1999, and so 1999 figures are the average of 1998 and 2000 numbers.

11. American women are less likely to continue in STEM fields than American men.

Figure 13: Science, Technology, Engineering, and Math (STEM) Degrees and STEM Employees who are Women

Source: Department of Education (n.d.).

The sample for degree completions is the NSF population of institutions. STEM degrees include awards in natural sciences, mathematics, computer science, engineering, and engineering technologies. The sample for the employment numbers includes individuals ages twenty-five to thirty-four who are working as scientists, engineers, computer developers, and mathematicians. Postsecondary teachers are excluded from employment numbers because their field of instruction could not be determined in all years. Data were not available for 1999, and so 1999 figures are the average of 1998 and 2000 numbers.

12. U.S. universities attract the brightest students from around the world, but immigration policy does not allow them to stay.

Figure 14: PhDs Awarded by U.S. Universities to International Students

Source: NSF (n.d.).

The sample for degree completions is the NSF population of institutions. International students receiving degrees are those studying in the United States as temporary residents, not including permanent residents or naturalized citizens. STEM fields are defined to include aerospace engineering, chemical engineering, civil engineering, electrical engineering, mechanical engineering, materials engineering, industrial engineering, other engineering, astronomy, chemistry, physics, other physical sciences, atmospheric sciences, earth sciences, oceanography, mathematics and statistics, computer science, and biological sciences.

References

- Aguiar, Mark, and Erik Hurst. 2007. "Measuring Trends in Leisure: The Allocation of Time Over Five Decades." *The Quarterly Journal of Economics*, 122 (3), 969–1006. Available at <http://qje.oxfordjournals.org/content/122/3/969.short>.
- Bowden, Sue, and Avner Offer. 1994. "Household Appliances and the Use of Time: The United States and Britain Since the 1920s." *The Economic History Review* 47 (4): 725–48.
- Bureau of Economic Analysis (BEA). n.d. "Interactive Access to National Income and Product Accounts Tables." Available at <http://www.bea.gov/national/nipaweb/index.asp>.
- Bureau of Labor Statistics (BLS). 2011. "Industry Labor Productivity and Costs: Indexes, 1987–2009." Available at <http://www.bls.gov/lpc/iprprodydata.htm>.
- Bureau of Labor Statistics (BLS). n.d. "Nonfarm Business Sector: Implicit Price Deflator (IPDNBS)." Available at <http://research.stlouisfed.org/fred2/series/IPDNBS>.
- Census Bureau, n.d.a. "Income: People." Available at <http://www.census.gov/hhes/www/income/data/historical/people/index.html>.
- Census Bureau. n.d.b. "Monthly & Annual Retail Trade Report." Last modified July 14, 2011. Available at <http://www.census.gov/retail>.
- Census Bureau. n.d.c. "U.S. Census Bureau Announces 2010 Census Population Counts—Apportionment Counts Delivered to President." Available at <http://2010.census.gov/news/releases/operations/cb10-cn93.html>.
- Centers for Disease Control and Prevention (CDC). 1999. "Achievements in Public Health, 1900–1999: Control of Infectious Diseases." *Morbidity and Mortality Weekly Report* 48 (29): 621–29.
- Cutler, David, and Grant Miller. 2005. "The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States." *Demography* 42 (1, February): 1–22.
- Department of Education. n.d. "National Center for Education Statistics, Higher Education General Information Survey (HEGIS), Degrees and Other Formal Awards Conferred, Surveys (1970–1971 Through 1985–1986) and Integrated Postsecondary Education Data System (IPEDS), Completions Survey (IPEDS-C:91-96) (1986–1987 Through 2008–2009 and Fall 2001 through Fall 2009)." Accessed through WebCASPAR.
- Greenstone, Michael, and Adam Looney. 2011 (June). "Where Is the Best Place to Invest \$102,000: In Stocks, Bonds, or a College Degree?" The Hamilton Project, Washington, DC. Available at http://www.brookings.edu/papers/2011/0625_education_greenstone_looney.aspx.
- Greenstone, Michael, and Adam Looney. 2011 (April). *Women in the Workforce: Is Wage Stagnation Catching Up to Them Too?* (Brookings Up Front Blog). Available at http://www.brookings.edu/opinions/2011/0401_jobs_greenstone_looney.aspx.
- Hausman, Jerry, and Ephraim Leibtag. 2005. "Consumer Benefits from Increased Competition in Shopping Outlets: Measuring the Effect of Wal-Mart." NBER Working Paper 11809, National Bureau of Economic Research, Cambridge, MA.
- Jensen, Robert. 2007. "The Digital Divide: Information (Technology), Market Performance and Welfare in the South Indian Fisheries Sector." *The Quarterly Journal of Economics* 122 (3): 879–924.
- King, Miriam, Steven Ruggles, J. Trent Alexander, Sarah Flood, Katie Genadek, Matthew B. Schroeder, Brandon Trampe, and Rebecca Vick. 2010. "Integrated Public Use Microdata Series, Current Population Survey (CPS): Version 3.0." [Machine-readable database.] Minneapolis: University of Minnesota.
- Moravec, Hans. n.d. "Robots." *Power and Presence: Numerical Data for the Power Curve*, Chap. 3. Data available at <http://www.frc.ri.cmu.edu/~hpm/book97/ch3/processor.list.txt>.
- National Center for Health Statistics. n.d.a. "U.S. Decennial Life Tables, National Center for Health Statistics," 1901–1960. Center for Disease Controls and Prevention, Atlanta, GA. Available at http://www.cdc.gov/nchs/products/life_tables.htm.
- National Center for Health Statistics. n.d.b. "Vital and Health Statistics Series," 1900–1978. Center for Disease Controls and Prevention, Atlanta, GA. Available at <http://www.cdc.gov/nchs/products/vsus.htm>.
- National Science Foundation (NSF). n.d. "NSF Survey of Earned Doctorates (SED)/Doctorate Records File," 1966–2009. Accessed through WebCASPAR.
- National Science Foundation (NSF). 2008. "National Patterns of R&D Resources: 2008 Data Update." Available at http://www.nsf.gov/statistics/nsf10314/content.cfm?pub_id=4000&id=2.
- Office of Management and Budget (OMB). n.d. "Historical Tables." Available at <http://www.whitehouse.gov/omb/budget/Historicals>.
- Organisation for Economic Co-operation and Development (OECD). 2008. "Graduates by Field of Education." OECD. StatExtracts. Available at <http://stats.oecd.org/Index.aspx?DatasetCode=RGRADSTY>.
- Patent and Trademark Office. n.d. "USPTO Annual Reports: Performance and Accountability Reports," 1990–2010. Available at <http://www.uspto.gov/about/stratplan/ar/index.jsp>.
- President's Council of Advisors on Science and Technology. 2011 (June). "Report to the President on Ensuring American Leadership in Advanced Manufacturing." Executive Office of the President. Available at <http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-advanced-manufacturing-june2011.pdf>.

- Ruggles, Steven, J. Trent Alexander, Katie Genadek, Ronald Goeken, Matthew B. Schroeder, and Matthew Sobek. 2010. "Integrated Public Use Microdata Series (IPUMS-USA): Version 5.0." [Machine-readable database.] Minneapolis: University of Minnesota.
- Williams, Karel, Colin Haslam, and John William. 1992. "Ford versus 'Fordism': The Beginning of Mass Production?" *Work, Employment and Society* 6 (4): 22.
- World Bank. n.d. "Indicators: World Development Indicators," 1966–2007. Available at <http://data.worldbank.org/indicator>.



ADVISORY COUNCIL

GEORGE A. AKERLOF
Koshland Professor of Economics
University of California at Berkeley

ROGER C. ALTMAN
Founder & Chairman
Evercore Partners

HOWARD P. BERKOWITZ
Managing Director
BlackRock

ALAN S. BLINDER
Gordon S. Rentschler Memorial Professor
of Economics & Public Affairs
Princeton University

TIMOTHY C. COLLINS
Senior Managing Director
& Chief Executive Officer
Ripplewood Holding, LLC

ROBERT CUMBY
Professor of Economics
Georgetown University

JOHN DEUTCH
Institute Professor
Massachusetts Institute of Technology

KAREN DYNAN
Vice President & Co-Director
of Economic Studies
Senior Fellow, The Brookings Institution

CHRISTOPHER EDLEY, JR.
Dean and Professor, Boalt School of Law
University of California, Berkeley

MEEGHAN PRUNTY EDELSTEIN
Senior Advisor
The Hamilton Project

BLAIR W. EFFRON
Founding Partner
Centerview Partners LLC

JUDY FEDER
Professor of Public Policy
Georgetown University
Senior Fellow, Center for American Progress

ROLAND FRYER
Robert M. Beren Professor of Economics
Harvard University and CEO, EdLabs

MARK GALLOGLY
Managing Principal
Centerbridge Partners

TED GAYER
Senior Fellow & Co-Director
of Economic Studies
The Brookings Institution

RICHARD GEPHARDT
President & Chief Executive Officer
Gephardt Government Affairs

MICHAEL D. GRANOFF
Chief Executive Officer
Pomona Capital

ROBERT GREENSTEIN
Executive Director
Center on Budget and Policy Priorities

CHUCK HAGEL
Distinguished Professor
Georgetown University
Former U.S. Senator

GLENN H. HUTCHINS
Co-Founder and Co-Chief Executive
Silver Lake

JIM JOHNSON
Vice Chairman
Perseus LLC

LAWRENCE KATZ
Elisabeth Allison Professor of Economics
Harvard University

MARK MCKINNON
Vice Chairman
Public Strategies, Inc.

ERIC MINDICH
Chief Executive Officer
Eton Park Capital Management

SUZANNE NORA JOHNSON
Former Vice Chairman
Goldman Sachs Group, Inc.

PETER ORSZAG
Vice Chairman of Global Banking
Citigroup, Inc.

RICHARD PERRY
Chief Executive Officer
Perry Capital

PENNY PRITZKER
Chairman of the Board
TransUnion

ROBERT REISCHAUER
President
The Urban Institute

ALICE RIVLIN
Senior Fellow & Director
Greater Washington Research at Brookings
Professor of Public Policy
Georgetown University

ROBERT E. RUBIN
Co-Chair, Council on Foreign Relations
Former U.S. Treasury Secretary

DAVID RUBENSTEIN
Co-Founder & Managing Director
The Carlyle Group

LESLIE B. SAMUELS
Partner
Cleary Gottlieb Steen & Hamilton LLP

RALPH L. SCHLOSSTEIN
President & Chief Executive Officer
Evercore Partners

ERIC SCHMIDT
Executive Chairman
Google Inc.

ERIC SCHWARTZ
76 West Holdings

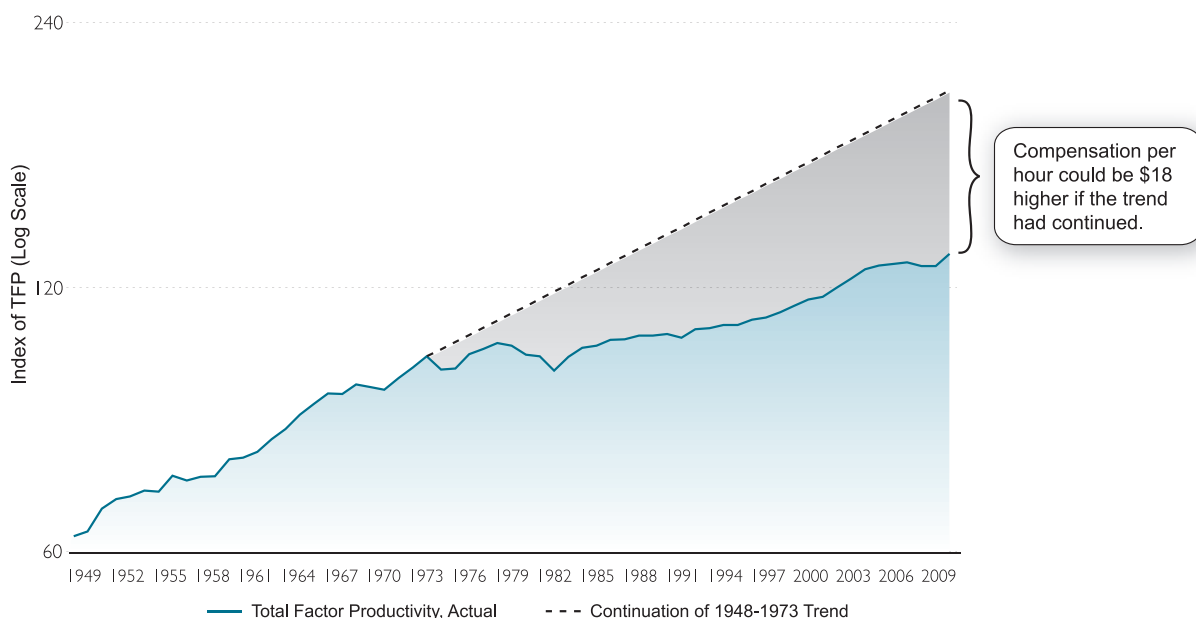
THOMAS F. STEYER
Senior Managing Member
Farallon Capital Management, L.L.C.

LAWRENCE H. SUMMERS
Charles W. Eliot University Professor
and Former U.S. Treasury Secretary
Harvard University

LAURA D'ANDREA TYSON
S.K. and Angela Chan Professor of
Global Management, Haas School of
Business University of California, Berkeley

MICHAEL GREENSTONE
Director

Total Factor Productivity



Innovation Facts:

1. Innovation drives economic growth and raises wages.
2. Innovation improves U.S. life expectancy.
3. Innovation makes technology affordable.
4. New organizational structures lead to rising standards of living.
5. New household technologies allow more time for family and leisure.
6. The pace of American innovation has slowed during the past four decades.
7. Innovation has failed to increase wages for a substantial number of Americans.
8. Significant barriers to innovation exist in the government and the private sector.
9. Federal support for research & development has declined in recent years.
10. Relatively few U.S. college students study fields critical to innovation.
11. American women are less likely to continue in STEM fields than American men.
12. U.S. policy makes it difficult for international students to stay and work.



1775 Massachusetts Ave., NW
Washington, DC 20036

(202) 797-6279

BROOKINGS



Printed on recycled paper.

WWW.HAMILTONPROJECT.ORG