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The Future of Work in the Age of the Machine

A Hamilton Project Framing Paper

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Introduction

Recent developments in technology, including the proliferation of smart machines, networked communication, and digitization, have the potential to transform the economy in groundbreaking ways. But whether this rapid technological change will lead to increased economic prosperity that is broadly shared is far from clear.

The productivity of the U.S. economy has grown substantially since the 1970s, but the median American male worker's wage rose by just 3 percent from 1979 to 2014 (DeNavas-Walt and Proctor 2014). This so-called wage stagnation is not unique to the United States: over the past several decades, wages for middle-income jobs have increased at an anemic pace in developed countries around the globe. Meanwhile, the wages of the highest-skilled and highest-paid individuals have continued to increase steadily. There are growing gaps in wages and employment opportunities between these individuals and those at the middle and bottom of the wage distribution, and there is no reason to think that these labor market trends will be reversed any time soon.

Economists attribute tepid wage growth at the middle and bottom of the distribution to various secular trends, including enhanced globalization of the economy and the shrinking role of labor unions. But one factor in particular—technological change—might be playing an especially important role in driving the divergent labor market experiences of those with different types of skills.

As rapidly advancing computer power and automation technology change the nature of work and the future of the economy, our nation will face new and pressing challenges about how to educate more people for the jobs of the future, how to foster creation of high-paying jobs, and how to support those who struggle economically during the transition. A commitment to economic growth that is widely shared has been a fundamental tenet of The Hamilton Project since its inception. The Project has released numerous policy papers focused on the issues of access to higher education, effective training and skill development, and investments in our nation's infrastructure and workforce. In this framing paper, The Hamilton Project explores the debate about how computerization and machines might change the future of work and the economy, and what challenges and opportunities this presents for public policy.

Technology and Economic Growth

As the Industrial Revolution picked up speed in England at the beginning of the nineteenth century, a small group of textile artisans violently protested the introduction of mechanized looms in factories across the country. Sensing a threat to their livelihoods, the weavers smashed and burned the new power looms, attempting in vain to slow their proliferation.

The Luddites, as they were called, were revolting against a phenomenon that would fundamentally alter the economies of the world. Technological change would dramatically increase the productivity of labor, creating new possibilities in manufacturing, agriculture, mining, and transportation. While these changes ultimately raised the standard of living in industrialized countries, the Luddites, and many others, saw their jobs disappear (Easterly 2001).

There is a consensus that, historically, technological progress has created winners and losers, but over the long run, new technology has tended to create more jobs than it has destroyed, while increasing society's productivity and wealth. For example, between 1900 and 2000, the proportion of the U.S. workforce in agriculture fell from 41 percent to 2 percent, yet agricultural output rose dramatically and there was no long-term increase in the unemployment rate, even as a greater proportion of the population participated in the labor force (Autor 2014b). The children and grandchildren of the workers who might have tilled farmland in 1900 are now computer programmers, radiology technicians, and pilots—jobs created by technologies that were unknown in 1900. And nearly everyone is economically better off.

Consistent with historical experience, the productivity of the U.S. economy has grown substantially over the past three decades as computer processing power and information technology has also grown prodigiously. But economic gains over this period have not been broadly shared: those at the top of the earnings distribution are reaping a disproportionate share of the productivity gains. This raises the following question: Is this recent period a departure from the historical norm of long-term job creation? Or is it a lengthy adjustment period caused by the unprecedented pace of technological progress?

Furthermore, even if technology eventually *will* increase prosperity more broadly in the long run, what kind of dislocations will there be in the interim? Many jobs that recently provided a middle-class lifestyle to workers and their families—from machinists to stock clerks—have been disappearing. What happens to workers like these, whose jobs are no longer in demand due to technological substitutes? In a recent poll of Americans between the ages of twenty-five and fifty-four who were not working, 37 percent of those who reported wanting a job stated that technology was one reason they did not have one (Hamel, Firth, and Brodie 2014). Workers are concerned, and it is very much an open question what the future of labor will look like in the age of the advanced machine, and what adjustments our society needs to make in response.

Machines and the 21st-Century Economy

Economists have historically rejected the argument that an increase in labor productivity reduces employment in the long run. The argument would be sound if there were a finite amount of work, but new technology creates new demand for labor. Indeed, in the two centuries since the beginning of the Industrial Revolution, the workforce has continued to grow, and productivity and living standards have risen dramatically in developed countries.

To consider how this process operates, it is important to recognize that, while inventions or innovations may mean fewer labor hours are needed to make any particular good, labor-saving innovations tend to reduce the costs of producing each unit, resulting in lower prices. Lower prices, in turn, lead to higher demand for goods, and, correspondingly, to higher demand for workers. This phenomenon played out, for example, with Henry Ford's implementation of the assembly line in the production of the Model T: fewer workers were needed to make each car, but the price fell so significantly that many consumers could afford to buy one, in turn creating more employment opportunities. Furthermore, the transportation revolution indirectly created jobs in other industries, such as tourism, and raised overall productivity. For example, goods could be transported faster, more cheaply, and more reliably. Thus, even if the direct employment effects of the assembly line in car production were negative, the overall employment effects in the economy were very likely positive.

Why would the digital revolution be any different? One reason might be that automation and computing are advancing much more quickly than any technology since the Industrial Revolution. In addition, advances in computing and automation have the potential to touch almost every sector of the economy. Harvard economist and former Treasury Secretary Lawrence Summers has observed that the general-purpose aspect of software means that even the industries and jobs it creates are susceptible to rapid technological displacement (Summers 2014). Economist Tyler Cowen of George Mason University has argued that the rapid advance of machines and computing will create two classes in America: a highly skilled elite, making up about a tenth of the population, who will profit handsomely by learning to work alongside machines; and everyone else, who will see their wages stagnate or decline (Cowen 2013).

However, not all observers agree that today's digital revolution is more consequential than prior periods of technological change. Economist Robert Gordon of Northwestern University suggests that recent progress in computing and automation is less transformative than electrification, cars, and wireless communication, and perhaps even indoor plumbing. Previous advances that enabled people to communicate and travel rapidly over long distances, according to Gordon, may end up being more significant to society's advancement than anything to come in the twenty-first century (Gordon 2014a).[1]

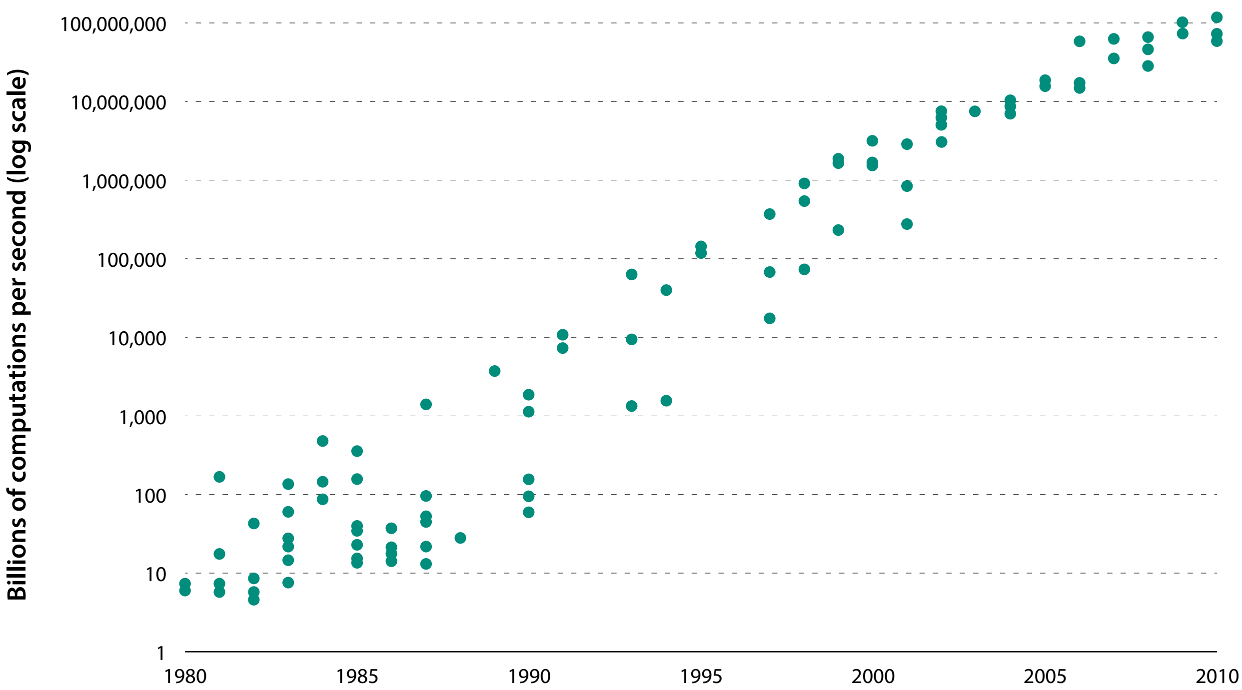
In a similar vein, Peter Thiel, the cofounder of PayPal and an early investor in Facebook, has frequently spoken about what he considers to be a stagnation in innovation, lamenting that the pace of technological development has stalled in fields that have tended to push boundaries: energy, pharmaceuticals, space exploration, and nanotechnology, among others (Milken Institute 2013).

Nonetheless, the cost of computing has fallen spectacularly since the 1970s, creating a strong incentive for employers to substitute cheap technology for expensive labor.[2] Figure 1 gives historical context for the dramatic and exponential increase in computer power per dollar (Nordhaus 2007). Consistent with this trend, information processing equipment and software rose from 8 percent to more than 30 percent of private, nonresidential investment between the years 1950 and 2012 (Autor 2014a). We see the results when we deposit a check using an iPhone, get driving directions from Google Maps, or use the self-checkout at the grocery. The gadgets of yesterday's science fiction, like self-driving cars and 3D printing, may be ubiquitous in a decade.

What do these developments imply for the usefulness of human workers? Computers are very good at certain

FIGURE 1.

One Dollar's Worth of Computer Power, 1980–2010



Source: Nordhaus (2007); updated data through 2010 from Nordhaus, personal website, http://www.econ.yale.edu/~nordhaus/homepage/, "Two Centuries of Productivity Growth in Computing."; authors' calculations.

Note: Nordhaus (2007) defines computer power as the rate at which computers and calculators can execute certain standard mathematical tasks, measured in computations per second. The data have been adjusted for purchasing power to year 2006 dollars.

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kinds of tasks, but still abysmal at others. While computer scientists have developed ways to automate highly routine tasks, like storing and retrieving information or performing precisely defined physical movements, machines still have a real challenge with nonroutine physical movement and abstract tasks.

Work involving visual and language recognition and in-person interaction has also proved mostly elusive for computers to master. That means that robots will have a hard time replacing labor in food service, cleaning, and caregiving. Innate human skills like dexterity, eyesight, and communication give humans a comparative advantage over machines in these tasks. That said, these jobs tend not to command high wages, in part because there is no shortage of workers to fill them.

MIT economist David Autor has emphasized that computers are very far from being able to use creativity, intuition, persuasion, and imaginative problem-solving, and they may never get there (Autor 2014a). That has insulated certain occupations from any displacement effect of computerization. Furthermore, Autor emphasizes the complementarity between machines and people, noting that most work activities require a mixture of tasks that must be accomplished jointly to produce the desired result—some ideally completed by a computer and some by a human. He writes that "productivity improvements in one set of tasks almost necessarily increase the economic value of the remaining tasks," implying that for some occupations (which can be viewed as a bundle of tasks) computerization increases the economic value of labor (Autor 2014a, 9).

Observed "wage polarization" during the 1990s was consistent with the view that technological developments during that decade tended to complement the abstract skills at the high end of the skill and wage distribution, and, in some instances, the nonroutine tasks performed in a number of lower-wage jobs. During the same period, there was a corresponding "job polarization" in both the U.S. economy and in a number of other Western economies, with job growth occurring in the lowest and highest parts of the skill distribution, while the middle sagged (Goos, Manning, and Salomons 2009, 2011).

It is worth noting that additional, related forces have been at work over the same period, including the continued erosion of labor institutions (such as unions) and the forward march of the globalization of trade (Autor, Dorn, Hanson, and Song 2014). These trends accentuate the advantages of those with highly demanded, scarcely supplied skills and weaken the relative position of less-skilled workers.

Wage and employment patterns from the 2000s do not follow the patterns observed during the 1990s as closely, raising questions about whether employment polarization along these lines will continue in the years ahead. Scholars including Autor (2014a) and Shierholz, Mishel, and Schmidt (2013) have observed that, in the 2000s, employment and wage polarization patterns have not continued to move together, with employment growth generally limited to the bottom end of the skill distribution and rapid wage growth generally occurring only at the top end of the distribution. This presents the undesirable possibility that a trend of employment growth in high-wage jobs is coming to an end.

Technology and the Role of Education

The economic story is not just about how technological changes increase the demand for goods and services and for increasingly skilled workers to produce them. How the story plays out depends crucially on how labor supply responds.

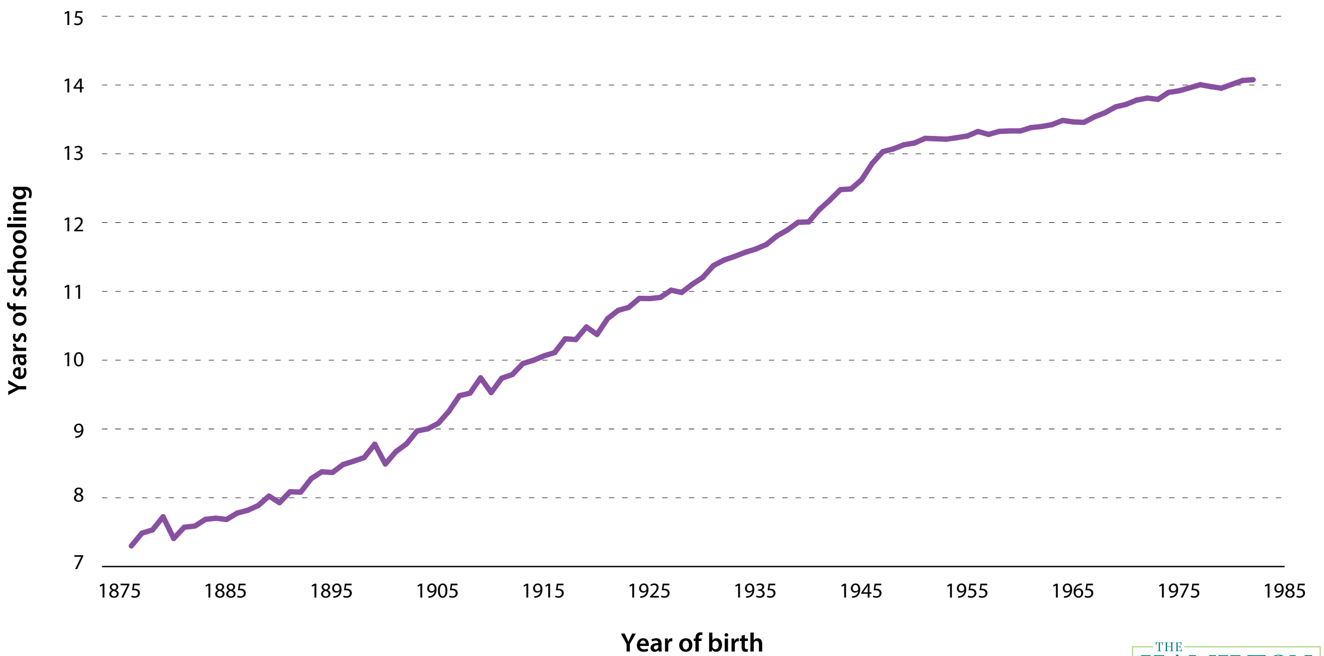
In their 2008 book *The Race between Education and Technology*, Claudia Goldin and Lawrence Katz make the case that the U.S. economy prospered during the twentieth century in large part because the educational attainment of the U.S. population raced with the technological advances that tended to increase the relative demand for skill. As shown in figure 2—updated from Goldin and Katz (2008)—the supply of educated Americans increased greatly and steadily from 1900 to around 1980. Much of this growth, especially in the early part of the century, reflected our nation's commitment to a secondary school system that was essentially free and open to all.

Because there was an increasing supply of educated Americans to meet the increasing demand for skills, inequality did not rise dramatically and economic gains were broadly shared.

But things changed in the later part of the century. Even as the advance of technology has accelerated—along with apparent wage gains from working with it—educational attainment has not kept up. Historically, successive generations steadily attained more education, at a rate of approximately one year of schooling every decade. Individuals born in 1930 averaged about eleven years of schooling by the time they reached age thirty, compared

FIGURE 2.

Years of Schooling at Age 30, by Birth Cohort, 1876–1982



Source: Goldin and Katz (2008) using 1940–2000 Integrated Public Use Microdata Series (IPUMS); updated data through 1982 birth cohort from Goldin and Katz, personal communication via email on February 9, 2015.

with thirteen years for people born in 1950. But for individuals born around 1950 and later, this pace has slowed dramatically (see figure 2). Goldin and Katz (2008) succinctly capture the essence of the story as follows: "In the first half of the century, education raced ahead of technology, but later in the century, technology raced ahead of educational gains" (p. 8).

To the extent that more education—or more of certain types of education—is necessary for someone to capture high wages in the age of advanced computing, networking, and big data, what the future will mean for shared prosperity will likely rest on the choices Americans make about how to educate our population.

Not only will it be imperative to increase the overall educational attainment of a larger share of the American population, but the provision of education will have to be effective and appropriately tailored to the demands of today's global, technology-demanding economy. Our system of primary and secondary school education will need to perform better, in terms of educating our students in math and science, in teaching them to write and communicate persuasively, and in giving them opportunities to develop their skills of team cooperation and leadership. Our educational system needs to foster talent at all levels.

Our system of higher education will need to reach more students, including those from economically disadvantaged backgrounds, and classroom instruction cannot be divorced from the demands of the labor market. Some students will benefit from targeted training in industry-specific skills. But, given that the labor market is dynamic, those same students will need to learn to be adaptive and acquire sufficient general skills that will enable them to move across jobs as the workplace evolves. There will also have to be ample opportunities for lifelong learning, to help older workers who need to increase and enhance their skills in later years. Ultimately, institutions of higher education need to train workers with specific skills, as well as produce a thriving population of managers, professionals, and entrepreneurs.

However, even if we do manage to meet these educational challenges, the future is uncertain. Shifts in labor demand might come faster than workers can respond, threatening even those with advanced levels of education.

Technology and Business Innovation

In their best-selling book *The Second Machine Age*, MIT research scientists Erik Brynjolfsson and Andrew McAfee (2014) suggest that neither workers nor capitalists will be the real winners in the economy of the future. Instead, the rapid proliferation of digital technology will allow a third class—people who can create new products, services, and business models—to prosper immensely. This view highlights the potential challenge of delivering an acceptable standard of living for everyone outside this innovator class.

This line of reasoning also underscores the critical importance of a thriving, innovative business sector. Indeed, whether new technology will make the average American worker better off will depend in part on the success of entrepreneurship in the United States. If advances in digital technology can be harnessed to create new and better businesses, workers will have a better shot at sharing the economy's growing prosperity. But if entrepreneurship declines, there is no guarantee that new technology will improve overall social welfare.

Unfortunately there is reason to worry about the state of business dynamism in the United States. Hathaway and Litan (2014) document a decline in new firm formation over the past several decades. Similarly, Haltiwanger, Hathaway, and Miranda (2014) show a sustained reduction in business dynamism—the process of more-competitive firms replacing less-competitive ones—across a broad range of sectors in the U.S. economy, even in the high-tech sector. The societal effects of rapidly advancing computer power and automation will in part depend on whether this trend can be reversed—whether entrepreneurs will capitalize on new technological possibilities to create competitive, dynamic organizations.

Fostering business creation and entrepreneurship in the United States will require sound fiscal and economic policies, smart regulatory practices, robust investment in infrastructure, and immigration policies that attract brilliant minds from the world over.

Conclusion

There is a range of thoughtful views on just what the future of work in the age of the smart machine will look like. The pessimistic view predicts that in the long run only a small fraction of the population will have the talent and education necessary to work alongside machines. The optimistic view predicts that advances in artificial intelligence and broad technological development will create employment possibilities that we cannot yet begin to imagine.

Both views present challenges. To realize the optimistic outcome will require a major commitment to increasing education and skill levels and also to fostering business and organization innovation. The pessimistic view makes meeting those challenges even more imperative, if we are to avoid the scenario where a substantial portion of our society is deprived of the livelihood and dignity that comes with a well-paying job. There is also the pressing question of what we are prepared to do as a society to support those who are not able to command a high-wage job, either because of a lack of skills or a lack of jobs. Rising to these challenges with innovative policies and a commitment to broad-based economic prosperity is consistent with The Hamilton Project's mission and purpose.

Acknowledgments

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Endnotes

1. Though Gordon is neither particularly impressed by nor worried about the impact of technological change on the future of work, he does argue that there are four important headwinds slowing U.S. economic growth, leading to a bleak outlook: demographics, education, inequality, and high debt-to-GDP ratios (Gordon 2014b).
2. Gordon E. Moore predicted in 1965 that the processing power of computers would grow exponentially, with the number of transistors on an integrated circuit doubling every eighteen months. Known as Moore's Law, this observation now has fairly strong empirical support, and has coincided with a spectacular decline in the cost of computing since the 1970s.

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The Hamilton Project seeks to advance America's promise of opportunity, prosperity, and growth. We believe that today's increasingly competitive global economy demands public policy ideas commensurate with the challenges of the 21st Century. 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.

Our strategy calls for combining public investment, 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. 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. The guiding principles of the Project remain consistent with these views.

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