Confronting Dystopia

The New Technological Revolution and the Future of Work

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2

The Rise of the Robots

Impact on Unemployment and Inequality

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The fear that machines might someday displace workers and produce long-term structural unemployment has a long history, stretching back, at a minimum, to the Luddite revolts that took place in England just over two hundred years ago. In the years since, the alarm has been raised again and again.

One of the most notable instances occurred in March of 1964, when a prominent group of intellectuals sent a formal document known as the "Triple Revolution Report" to President Lyndon Johnson. The report warned that industrial automation was poised to throw millions of people out of work and create economic and social upheaval. In an accompanying letter, the authors wrote that unless the government took action, "the nation [would] be thrown into unprecedented economic and social

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The author used the FRED (Federal Reserve Economic Data) database from the Federal Reserve Bank of St. Louis to assemble some of the data used in this paper. See the reference list for information on the specific series used.

disorder."[1] The feared disruption, of course, did not occur, and the report has now been largely forgotten.

Given this long record of false alarms, contemporary economists are generally dismissive of arguments that technological progress might lead to unemployment as well as falling wages and soaring income inequality. History shows that the economy has consistently adjusted to advancing technology by creating new employment opportunities and that these new jobs often require more skills and pay higher wages.

The post–World War II period in the United States offers an especially powerful demonstration of the historical synergy between technological progress and increasing overall prosperity. During this "golden age" of the American industrial economy, wages for nearly all workers increased as productivity soared. The result was the emergence of a massive US middle class. Workers, in turn, increased their spending in line with their rising incomes, creating strong demand for the products and services being produced by the economy. This virtuous cycle encompassing production and consumption drove America's economic growth and prosperity and gradually became the model for other industrialized countries throughout the world.

The mechanization of the US agricultural sector offers one of the most extreme historical examples of technologically induced job losses. In the late 1800s, about three-quarters of workers in the United States were employed in agriculture. Today, the number is between 1 and 2 percent. Advancing agricultural technology irreversibly destroyed millions of these jobs. This did, in fact, result in significant short- and medium-term unemployment as displaced farm workers migrated to cities in search of factory work. However, the unemployed workers were eventually accommodated by the rising manufacturing and service sectors and, over the long run, average wages as well as overall prosperity increased dramatically.

The conventional wisdom suggests that we should expect a similar transition to unfold in the face of today's rapid advances in robotics and artificial intelligence. However, there are important reasons to be concerned that this time might turn out to be very different. Because information technology accelerates (roughly doubling every two years, according to the well-known Moore's Law) rather than increasing in a linear fashion, we can anticipate that the coming years and decades will see far more progress than we might expect based on an analysis of history. In the future, the impact of automation will no longer be limited to lower-wage workers with limited skills and educations. Technologies such as artificial

intelligence, machine learning, and software automation will increasingly enable computers to do jobs that require significant training and education. College graduates who take knowledge-based jobs will find themselves threatened not only by low-wage offshore competitors, but also by machines and software algorithms that can perform sophisticated analysis and decision making.

Continuing progress in manufacturing automation and the introduction of advanced commercial robots and self-service technologies will likewise continue to diminish opportunities for lower-skilled and less-educated workers. Technological progress is relentless, and artificial intelligence seems likely to eventually approach the point where it will match or exceed the average worker's ability to perform most routine, predictable work tasks. At that point, nearly all rational businesses will be faced with a powerful incentive to substitute machines for workers.

In the past, disruptive labor-saving technologies have typically been specialized, and they have made their effect felt on a sector-by-sector basis. Workers have adapted by moving from routine jobs in one area to routine jobs in some new emerging industry. For example, in the United States, workers transitioned from farms to factories and then ultimately to service jobs, which now provide the vast majority of employment. Today's artificial intelligence (AI) and robotics technology, by contrast, is nothing like the mechanical innovations that transformed agriculture. Information technology has far more broad-based implications: it is a general-purpose technology that has invaded, and will increasingly disrupt, every sector of the economy. For the first time in history, computers and machines are beginning to take on intellectual tasks that were once the exclusive province of the human brain. Information technology will continue to accelerate, and is certain to be tightly integrated into any industries that arise in the future. The upshot is that it seems very unlikely that there will be new labor-intensive employment sectors capable of absorbing the millions of workers displaced from existing industries as technology advances.[2]

Evidence of information technology's impact on employment can already be found in the industries that have emerged over the past decade or two. Companies such as Google and Facebook have achieved enormous influence and market valuations, with workforces a fraction of the size of those found in more traditional industries. In 2012, for example, Google generated about US$14 billion in earnings while employing just thirty-eight thousand people. Compare that with General Motors, which

peaked at roughly 840,000 employees in 1979, while earning only US$11 billion (measured in 2012 dollars)—about 20 percent less than Google.

Economic Trends That Suggest Technology Is Already Having an Impact

Soaring inequality in the United States, in terms of both income and wealth, has recently become a widely discussed and debated topic. Over the seventeen-year period between 1993 and 2010, more than half of the growth in US national income was captured by the top 1 percent of households. ("Politics" 2012). Emmanuel Saez, an economist at the University of California, Berkeley, found (2013) that during the economic recovery between 2009 and 2012, a full 95 percent of US income gains likewise went to the top 1 percent. Wealth inequality is even more extreme. The top 5 percent of US households own nearly two-thirds of private assets, and the combined net worth of the four hundred wealthiest Americans is now greater than that of the 150 million people at the bottom of the income distribution.

A number of theories have been put forward to explain the relentless increase in inequality. These include a rightward drift in politics and policy that began with the administration of President Ronald Reagan and, in particular, the almost complete elimination of organized labor in the US private sector. Globalization, especially the migration of factory jobs to China, is another often-cited driver of inequality. The increasing dominance of the US financial sector, the extraordinary rise in compensation paid to corporate executives and superstar entertainers, and assortative mating—in which individuals with similar educational backgrounds and incomes tend to marry—have all been singled out as important contributing factors.

While it is very likely that all these factors have contributed to the relentless, decades-long drive toward increased inequality in the United States, and to a lesser degree in many other countries, a number of important economic trends—especially when considered together—point to the importance of advancing technology. In addition, it is critical to keep in mind that, because information technology continues to be driven by exponential progress, there is good reason to expect that it

will rise above other factors and become the dominant force shaping the future economy.

Stagnant Wages and Consistently Increasing Productivity

Between the end of World War II and 1973, wages for typical workers in the United States rose in nearly perfect lockstep with increasing productivity. In 1973, however, wages for private-sector production and nonsupervisory workers (a category that includes over 60 percent of the total US workforce and about 80 percent of private-sector workers) reached a historical peak of US$767 (measured in 2013 dollars)—and then went into a decades-long decline. By 2013, a comparable worker earned only about US$664, or about 13 percent less than in 1973 ("Hours" 2013). Over the same four decades, productivity (or real output per hour) rose by nearly 110 percent.

Figure 2.1 shows how compensation (wages plus the value of benefits) for US workers and productivity growth in percentage terms compare over different periods going back to the years following World War II. The chart makes it clear that productivity has grown significantly faster

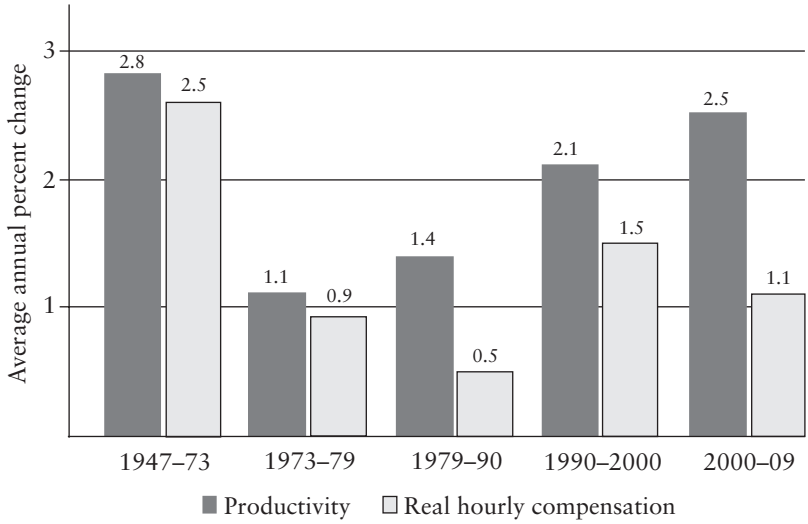

Figure 2.1 Growth in productivity vs. real hourly compensation in the US nonfarm business sector. US Bureau of Labor Statistics 2011.

than compensation in every decade since 1979. The difference is especially notable from 2000 to 2009: productivity growth during this period is more than double the corresponding increase in compensation. Indeed, since the trend reversed in the 1970s, the gap between productivity and compensation appears to be consistently increasing over time. This widening gap illustrates the extent to which the fruits of technological progress throughout the economy are being captured almost entirely by business owners, investors, and others at the top of the income distribution, rather than by average workers.

Declining Labor Share of National Income

The share of national income going to labor vs. capital has historically been quite stable. In the United States in the two decades following World War II, labor's share of income varied in a relatively narrow range, averaging somewhere around 64 to 66 percent. Beginning in the early 1970s, the US labor share began to decline; in the years following 2000, the decline has become far more precipitous. (See figure 2.2).

This decline of labor's share of national income relative to capital is not limited to the United States. In a 2013 analysis, economists Loukas Karabarbounis and Brent Neiman of the University of Chicago found that

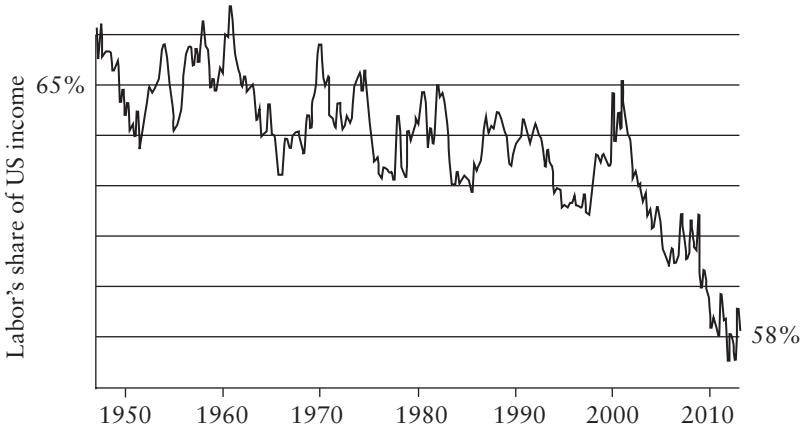

Figure 2.2 The decline in labor's share of US income. US Bureau of Labor Statistics and Federal Reserve Bank of St. Louis (FRED), using data from Jacobson and Occhino 2012.

forty-two out of the fifty-nine countries they analyzed showed a significant decline in labor's share. Japan, Canada, France, Italy, Germany, and China all had more substantial declines than the United States, measured over a ten-year period. In China, it fell at about three times the US rate. Karabarbounis and Neiman (2013, 1) conclude that "efficiency gains in capital producing sectors, often attributed to advances in information technology and the computer age, induced firms to shift away from labor and toward capital to such a large extent that the labor share of income declined."

Job Market Polarization

David Autor, an economist at the Massachusetts Institute of Technology, has done extensive analysis of the "hollowing out" or polarization of the job market. Polarization happens when solid middle-skill jobs that provide middle-class incomes disappear and are replaced with large numbers of low-wage, low-skill jobs (typically in the service sector, in areas such as fast food and retail), as well as high-skill jobs that generally require advanced education and training. In research published in 2010, Autor identified four midrange occupational categories that have been dramatically affected: sales, office-administrative, production-craft-repair, and operators-fabricators-laborers. Between 1979 and 2009, the percentage of the US workforce employed in these four areas fell from 57.3 percent to 45.7 percent; the rate of decline became more rapid between 2007 and 2009. As with the fall in labor's share of national income, polarization is not an exclusively American trend. It is occurring in a variety of industrialized countries. Between 1993 and 2006, sixteen European Union countries experienced a significant decline in the fraction of their workforce employed in midrange occupations. Autor (2010, 2) suggests that the primary reason for polarization is "the automation of routine work and, to a smaller extent, the international integration of labor markets through trade and, more recently, offshoring."

Declining Labor Force Participation and an Explosion in Disability

The US labor force participation rate—a measure of the percentage of adults aged eighteen to sixty-four who are currently employed or actively seeking a job—peaked at about 67 percent in 2000 and has been in decline

ever since. By 2013, the rate had fallen below 64 percent. The participation rate for people aged twenty-five to fifty-four, which includes most who are beyond the age where they are likely to be in school full time and yet not old enough to retire, also declined from a high of 84.5 percent to 81 percent as of 2013 (Federal).

There has also been an explosion in applications for the US Social Security disability program, which is intended for workers who suffer serious workplace injuries. Between 2000 and 2011, the number of disability applications more than doubled, from roughly 1.2 million per year to nearly three million (Van Zandweghe 2012). This suggests the possibility that many discouraged workers are relying on the disability program as a kind of unemployment insurance system.

Less Job Creation and Longer Jobless Recoveries

In nearly every decade since the 1960s, the US economy has created fewer new jobs, in percentage terms, than in the preceding ten-year period. The 1990s nearly matched the 1980s, with about 20 percent growth in employment, but this was heavily driven by a surge of new jobs that appeared during the technology boom in the second half of the decade. Table 2.1 shows the percentage of new jobs generated in each decade.

In addition, when recessions occur it is taking the economy longer and longer to return to the previous level of employment. Table 2.2 shows the length of recovery for recent recessions, measured in months from the start of the recession. The Great Recession of 2007–2009 unleashed a jobless recovery of historic proportions. It took about six years for employment to return to its pre-crisis level.

Table 2.1 US job creation by decade

Decade	Percentage increase in employment
1960s	31
1970s	28
1980s	20
1990s	20
2000s	0

Source: US Bureau of Labor Statistics and Federal Reserve Bank of St. Louis (FRED).

Table 2.2 Months for US employment to recover (from start of recession)

Recession	Months to recover
1974–1975	15
1981–1982	27
1990–1991	30
2001	46
2007–2009	80

Source: US Bureau of Labor Statistics and Federal Reserve Bank of St. Louis (FRED).

Technology Offers the Best Explanation for These Trends

Each of these trends has been the subject of analysis and research by economists, and a number of competing theories have been put forward to explain them. Many factors (including, for example, globalization, demographics, and political shifts) have doubtless played a significant role and may provide at least partial explanations for one or more of these trends. However, when all of the trends are considered together, a strong case can be made that technology is the most important underlying factor. Note, for example, that both a decline in labor's share and job market polarization have been found in a number of countries with vastly different political orientations. Germany and Canada continue to have influential organized labor movements, while unions have been almost entirely eliminated from the US private sector. China, a country that benefits greatly from globalization, has seen a rapid collapse in the share of national income labor. Clearly, some global force is exerting a powerful influence. Technology is arguably the only factor that can reasonably explain all of these trends in all the countries in which they have been observed.

Occupations Affected by Automation, Now and in the Near Future

Examples of the rapid progress being made in robotics and AI are widespread, and more appear on nearly a daily basis. Industrial Perception, Inc., a small company (now owned by Alphabet/Google) based in Silicon Valley, California, has built a robot capable of visually perceiving and

moving boxes of various shapes and sizes. In a remarkable demonstration of the kind of cross-fertilization that is common in the information technology sector, the robot uses an advanced three-dimensional machine vision system that was originally developed for the Microsoft Kinect—a US$150 add-on for the company's video game system. Industrial Perception expects its robot to eventually be able to continually move, load, or unload boxes at a rate of one every second, far exceeding the capability of a human worker (Markoff 2012). It goes without saying that this robot will never get tired, never suffer a back injury, and certainly never file a worker's compensation claim. This is just one example of how robotic technology is rapidly encroaching on jobs that, until now, have been relatively safe from automation. As the technology becomes more affordable, reliable, and ubiquitous, it seems poised to have a disruptive impact on jobs in the materials handling arena.

Low-wage jobs in industries such as fast food and retail will likewise be increasingly susceptible to automation as well as vastly improved self-service technologies, often powered by mobile phone apps. Retail jobs will also continue to be threatened by the continuing onslaught from Amazon and other online retailers. Amazon itself relies increasingly on labor-saving technology, and in 2012 purchased Kiva Systems, a company that manufactures robots used in warehouse automation.

It seems inevitable that many jobs in the fast-food industry will ultimately be threatened by automation. Venture-backed startup companies are already focusing on robotic production of hamburgers and pizza. The strong political movement in favor of a higher minimum wage in the United States may, to some extent, accelerate automation in the industry.

The advent of fully automated cars and trucks has the potential to directly threaten millions of jobs for professional drivers, possibly within the next decade or two. In a number of US states, driving a vehicle of some type is the most common occupational category, especially for non-college-educated men. Most analysts expect automated cars to evolve into shared resources (at least within urban areas). In other words, self-driving cars will operate like Uber or Lyft—but without the drivers. Indeed, both Uber and Lyft are actively investing in research and development of self-driving vehicle technology. If we eventually move toward a world in which most people do not own cars, millions more jobs and small businesses in areas such as auto repair and insurance could also eventually be

vulnerable as the automotive sector transitions from a widely distributed owner-operator model to centralized fleet ownership.

Highly skilled and college-educated workers are by no means exempt from the impact of these technologies. The "big data" phenomenon is resulting in new management approaches where vast amounts of information are analyzed for correlations that can be used to drive business decisions. The approach will often require fewer analysts and middle managers, as decisions are made algorithmically. Narrative Science, Inc., a Chicago-area company with approximately thirty employees, has developed a system capable of autonomously writing news articles and internal corporate reports. The system is first configured to analyze a data stream and then can continuously output reports and articles that contain intelligent analysis and are written in natural language. A number of top news sites use the company's service, including *Forbes* magazine. One of the company's cofounders thinks that within fifteen years, "more than 90 percent" of news articles will be written by computer algorithms (Levy 2012).

IBM's Watson computer, introduced in 2011, was another vivid illustration of the advances being made in systems that will influence knowledge-based work. Watson, which combines deep analysis with a remarkable facility with natural language, was able to prevail against the best human contestants in the television game show *Jeopardy*!—an unprecedented feat for a computer. Other skilled professions being affected include attorneys and paralegals (by software able to autonomously analyze documents and decide if they are relevant to legal cases), doctors specializing in radiology and pathology (by automated systems that can analyze medical images and perform tests on tissue samples), and pharmacists (by massive pharmacy robots already in many large hospitals that completely automate the medication-dispensing process).

The most startling advances in artificial intelligence are occurring in the field of "deep learning," a type of machine learning that is based on neural networks that loosely model the way biological brains work. Neural networks have been in use for basic pattern recognition tasks for decades; however, recent years have seen remarkable progress in building far more complex ("deep") networks with many layers of simulated neurons. Deep learning systems are already outperforming humans at recognizing visual images and have succeeded in at least basic real-time spoken-language

translation. In 2016, Google DeepMind software succeeded in defeating one of the world's best players of the ancient game of Go. Unlike chess, Go, which is very popular in Asian countries, cannot be approached with a "brute force" algorithm geared toward computing nearly every possible move. Instead, it must be approached using more humanlike thought. Remarkably, Google's system succeeded in part by training itself to play the game—and then rapidly achieved the ability to defeat virtually any human being.

This demonstrated propensity by artificial intelligence and machine learning to take on more intellectual tasks, and to climb the skills ladder and affect the jobs held by highly educated workers, is one of the most important, and disruptive, trends likely to unfold in the coming years and decades. The conventional solution to the automation of low-skill jobs has always been more education or retraining, so that the affected workers can move up to higher-skill work. As technology accelerates, this solution is likely to become ever less effective. In order to remain relevant, it will no longer be sufficient for workers to simply acquire new skills and move into a new type of routine, predictable work. Rather, they will have to find opportunities that involve genuinely nonroutine or creative tasks. Some workers will, of course, successfully make that transition, but there is a real question as to whether there will be enough of these jobs, as well as whether many workers will be capable of adapting.

The concern that robots and automation may eventually threaten huge numbers of jobs is supported by formal academic research. In 2013, Carl Benedikt Frey and Michael A. Osborne of the University of Oxford published research that includes a formal analysis of over seven hundred occupations tracked by the US Department of Labor. Frey and Osborne (2013, 38) concluded that about 47 percent of total US employment—more than sixty million jobs—will be highly susceptible to automation within roughly the next two decades.

Technology-Driven Inequality and Its Impact on Consumer Spending and Trade

Over the course of the two decades between 1992 and 2012, the percentage of total US consumer spending attributed to households in the

top 5 percent of the income distribution rose from 27 to 38 percent. Over the same period, the percentage of consumption associated with the bottom 80 percent of American consumers fell from 46.6 to 39 percent (Schwartz 2014). American economic growth is becoming more and more dependent on a small number of elite consumers with relatively high incomes.

In the decades leading up to the 2007 financial crisis, American consumers continued to spend more overall even as income became dramatically more concentrated at the top. Between 1972 and 2007, average spending as a share of disposable income increased from about 85 percent to over 93 percent. For most of that period, consumption was both the largest and fastest-growing component of US Gross Domestic Product (GDP) (Cynamon and Fazzari 2014).

This increase in overall consumption is quite surprising, because it is well-known to economists that higher-income households spend less of their total income (and save or invest much more) than do middle-class or poor households. We would logically have anticipated seeing weaker overall spending as an increasing share of national income was captured by a few households at the top of the income distribution, since these elite consumers would be inclined to spend a smaller fraction of their incomes.

In January 2014, economists Barry Cynamon of the Federal Reserve Bank of Saint Louis and Steven Fazzari of Washington University in St. Louis published a paper that attempted to explain this mystery of rising income inequality combined with increased overall consumer spending. They came to the conclusion that the long-term increase in American consumption was made possible by a dramatically increased debt load taken on by the lower 95 percent of American households. Between 1989 and 2007 the ratio of debt to income for the bottom 95 percent roughly doubled from around 80 percent to nearly 160 percent. For the top 5 percent of households, the same debt/income ratio saw little or no increase at all, staying at around 60 percent. The greatest increase in debt levels occurred while the US housing bubble was rapidly inflating in the years immediately leading up to the financial crisis. Cynamon and Fazzari (2014, 18) suggest that the debt burden taken on by the bottom 95 percent of US households ultimately proved unsustainable, and that "financial fragility created by unprecedented borrowing triggered the Great Recession when the inability to borrow more forced a drop in consumption."

Cynamon and Fazzari also found a dramatic difference in the top 5 percent vs. the bottom 95 percent during the recession recovery that began in 2009. By 2012, spending by the top 5 percent had increased by about 17 percent. The bottom 95 percent had seen no increase at all; spending remained at approximately 2008 levels. In other words, the recovery in overall consumer spending was powered entirely by consumers in the top 5 percent of households by income.

The recovery from the Great Recession has generally been characterized by soaring corporate earnings coupled with far less impressive increases in revenue. This demonstrates that the profits are coming from cost-cutting rather than market expansion.

Consumption in the United States is typically around 70 percent of GDP. An important future risk is that, as consumer spending becomes more and more concentrated among a small number of high-income households, it will become more and more difficult to sustain economic growth. Many of the households in the top 5 percent depend on knowledge-based or professional work for their relatively high incomes. As we saw earlier, many of these occupations are certain to be vulnerable to automation as advances in artificial intelligence and machine learning continue. Likewise, these advances could make it increasingly difficult for new college graduates to someday climb to the high income levels that will allow them to make outsized contributions to consumer spending. The result could turn out to be even more dramatic concentration in the number of households with sufficient purchasing power to sustain overall consumer spending as well as economic growth.

It is important to keep in mind that all final demand for products and services throughout any economy comes ultimately from household consumer spending and, to a lesser extent, spending by governments. While businesses, of course, also buy products and services, this does not constitute final demand. If a business is unable to sell its own output, it will stop purchasing inputs and, eventually, will close its doors. When machines or software replace workers (or, alternatively, deskill jobs so that wages are driven down to the minimum), that means less consumption. Machines do not create final demand. For example, a robot in a factory will use energy and require maintenance and spare parts, but these are inputs to the production process. If the factory's output cannot be sold, the robot will be shut down. The bottom line is that all demand across the economy

is ultimately dependent on purchases made by households—and the vast majority of households, in turn, are dependent on jobs for nearly their entire income.

Consumer Spending and Economic Growth

If rapid acceleration in robotics and artificial intelligence technologies eventually creates widespread unemployment or causes wages for a large fraction of households to fall, there is likely to be a substantial impact on consumer spending, and therefore on economic growth. If the technological impact comes in the form of software automation focused on relatively highly paid knowledge workers, who are responsible for a growing share of consumer spending, the resulting reduction in consumption could be especially significant.

In the coming decades, dramatic technological progress can be expected in all the advanced economies that are currently responsible for a large fraction of the consumer demand that is a critical driver of global trade. Robotics and automation will likewise have a substantial impact on the economy of China and other emerging countries. All this creates the potential for a situation where there are too few viable consumers to provide sufficient demand across the global economy. Indeed, many economies are already caught in a trap in which central banks (such as the US Federal Reserve) have been forced to maintain interest rates near zero levels. If technological progress in the coming years results in unemployment and even higher inequality, it will become even more difficult for central banks to raise interest rates and avoid deflation. The ultimate result could be little or no economic growth and possibly even financial crises if households again become overly dependent on debt as a means to maintain spending in the absence of rising incomes.

Impact on Developing Nations and the Global South

The impact of advancing technology will by no means be limited to advanced nations. In China, for example, robots are already having a dramatic impact on the labor-intensive factories that provide employment for

many millions of workers. Indeed, China is now by far the largest global market for industrial robots. Even so, the country's robot density—or the number of robots per one hundred workers—is among the lowest of all major manufacturing economies. In other words, the transition to automation remains at a very early stage: there is far more to come.

For those poorer countries that have not yet enjoyed the progress seen in China, the story may be especially grim. As I wrote in my 2015 book *Rise of the Robots*,

> The challenges faced by China are even more daunting for poorer countries, which are much further behind in the race against technology. As even the most labor-intensive areas of manufacturing begin to incorporate more automation, the historical path to prosperity may be poised to largely evaporate for these nations. According to one study, about 22 million factory jobs disappeared worldwide between 1995 and 2002. Over the same seven-year period, manufacturing output increased 30 percent. It is not at all clear how the poorest countries in Asia and Africa will manage to dramatically improve their prospects in a world that no longer needs untold millions of low-wage factory workers (Ford 2015).

The path to broad-based prosperity for developing countries has always been to build labor-intensive factories that provide jobs for large numbers of unskilled workers. There is evidence that this path is already beginning to erode. In 2015, Harvard economist Dani Rodrik published a paper documenting what he dubbed "premature deindustrialization." In other words, developing countries are losing their manufacturing jobs before they are able to climb the prosperity ladder that was navigated by advanced countries such as the United States in an era when technology was far less advanced. Mexico is one of the countries that Rodrik identifies as struggling to make the leap to prosperity in the robotic age (Rodrik 2015).

What Is the Solution?

Over the course of the coming decades, nations in both the developed and developing worlds will face the challenge of adapting to the impact of rapidly advancing robotics and artificial intelligence technology. The

goal should be to leverage the power of these technologies for the benefit of both society and the economy, while finding a way to mitigate the likely impact on employment opportunities, economic security, inequality, and consumer confidence. Historically, there has been only one conventional policy response to the advent of automation: to subject workers to ever more training and education in the hope that they can outrun the capability of the machines. As we have seen, artificial intelligence is proving adept at climbing the skills ladder, and jobs and tasks performed by highly educated workers such as journalists, lawyers, and radiologists are already being affected. As the rate of technological progress accelerates, it is easy to imagine a future in which workers are unable to keep up with the rate of change.

If education and retraining ultimately prove insufficient, we will eventually need to consider a more radical solution. We will have to find a way to restructure our economic system, and that will likely involve decoupling income from traditional jobs. Some form of guaranteed income or universal basic income (UBI) is the most viable way to do this. The essential idea is that a nation would provide every adult with at least at least a minimal guaranteed income that would provide essential economic security as well as the means to actively participate in the economy as a consumer and thus help drive overall economic growth.

Implementing a guaranteed income is certain to present a staggering political challenge, especially in the United States. Therefore, eventual success will require a pragmatic approach. In my two books, *Rise of the Robots* (2015) and *The Lights in the Tunnel* (2009), I suggested two ways that an absolutely "universal" and "unconditional" guaranteed income scheme might be modified to make it more effective, affordable, and, perhaps, politically palatable.

First, basic incentives could be incorporated into the income scheme. Most important would be an incentive to pursue further education. People who succeed in completing higher levels ought to receive somewhat higher basic incomes. In the absence of this, non–academically inclined students might be presented with a perverse incentive to simply drop out of school, knowing that they would, in any case, be eligible for the basic income. Education is a vitally important public good, and a well-educated population provides many benefits to society. Any basic income scheme should be designed to ensure that citizens continue to experience direct personal

gain from remaining in school and pursuing the highest level of education that is compatible with their ability. Such incentives might also be extended to other areas, such as meaningful contributions to communities or to humanistic or artistic endeavors. Indeed, a basic income with incentives built in might eventually offer at least a partial solution to the age-old complaint that the market economy does not place adequate value on many of the endeavors that are most critical to the positive development of both individuals and society as a whole.

Secondly, one of most important tenets of a strictly defined UBI is that the income is not means-tested. Everyone receives it unconditionally. This ensures that there is no disincentive to work or engage in entrepreneurial activity that will result in a higher overall income level. This is crucial to avoiding a "poverty trap" scenario, where those who receive the income are discouraged from improving their lot because of the risk that they will lose eligibility for their existing benefits. In theory, an unconditional income for everyone should also help to galvanize political support for the program. This approach is, however, much costlier than a guaranteed minimum income that is phased out as other income increases. I think there is middle ground that could reduce the overall cost of a basic income while making it more politically feasible: The income could be means-tested against "passive" income (pensions, social security, rents and royalties, investment income) but not against "active" income (wages, income from an actively managed small business, etc.). This would preserve the incentive to work or start a business while reducing the cost of the program. It would also improve the political optics by limiting the eligibility of those who already enjoy adequate guaranteed incomes from other sources.

It should be noted that a basic income scheme can, of course, be combined with other initiatives. One promising avenue might be policies geared toward encouraging "work sharing," in which jobs are shared in some way among more than one worker. This approach might be fairly simple to implement in blue-collar hourly positions (perhaps by simply mandating a reduction from the standard forty-hour week). It would likely be much more difficult to extend a work-sharing policy to skilled white-collar and professional occupations. The idea that a decreasing work burden could be shared goes back at least to John Maynard Keynes's 1930 essay "Economic Possibilities for our Grandchildren," in which he

envisioned a fifteen-hour workweek as an attempt to "spread the bread thin on the butter—to make what work there is still to be done to be as widely shared as possible" (Keynes 1930). Perhaps Keynes's vision will ultimately be realized, but current trends suggest that it is very unlikely that the market economy, left to its own devices, will produce sufficient incomes for part-time workers. Instead, it may come about through income supplementation via a UBI combined with explicit work-sharing policies.

It seems likely that practicality, and a willingness to address legitimate concerns about the creation of a disincentive to work, will be required if a basic income is ever to become politically viable. At this point in time, an obvious first step would be to initiate some pilot programs or small-scale experiments in order to test various basic income schemes. These experiments would provide data that might be used to craft an eventual program that could be scaled out at the national level.

We should begin this process as soon as possible. The history of universal health care in the United States offers a cautionary tale regarding the extreme sluggishness of the political process. It took the nation approximately eighty years from the time that Franklin Roosevelt proposed a national health insurance program until the implementation of the Affordable Care Act (Obamacare), something approaching universal health coverage. It's very unlikely that we will have anything close to that length of time as we attempt to navigate the coming transition. The progress of information technology continues to accelerate and the impact on the job market could well materialize long before we are prepared for it.

2. The Rise of the Robots

1. The text of "The Triple Revolution" and the letters cited are available on the Linus Pauling and the International Peace Movement pages at http://scarc.library.oregonstate.edu/coll/pauling/peace/papers/index.html.

2. Health care and elder care may well be the most promising sectors for future job growth, given the trend toward an aging population. However, there are unlikely to be enough of these jobs, and there are sure to be significant skill and personality mismatches—especially for less-skilled males. For example, is it realistic to assume that a large fraction of the 3.5 million truck drivers in the United States could transition into nursing or elder care jobs if and when they are displaced by the self-driving truck technologies that are already under development?

4. Expanding Job Opportunities through Global Green Growth

1. See Pollin et al. 2014; Pollin, Garrett-Peltier, Heintz, and Chakraborty 2015, Pollin and Chakraborty 2015; and Pollin, Garrett-Peltier, and Chakraborty 2015 in addition to my 2015 book cited above.

2. There have been sharp debates as to the extent of job creation that would have been generated through expanding the Keystone Pipeline. The figures cited here are from the US State Department: https://keystonepipeline-xl.state.gov/documents/organization/221135.pdf.

3. See chapter 6 and appendix 3 of Pollin, Garrett-Peltier, Heintz, and Chakraborty 2015 for a full discussion of the employment-estimating methodology used here. One point to clarify here is that I am not suggesting that spending $1 million on energy efficiency, clean renewable energy, or nonrenewable energy will produce an identical impact on either energy supply (through capacity expansion) or energy demand (through raising efficiency standards). I discuss the distinct effects created by spending a given amount of funds on efficiency, renewables, or nonrenewable energy in Pollin 2015 as well as, in greater depth, Pollin et al. 2014 and Pollin, Garrett-Peltier, Heintz, and Chakraborty 2015.

4. Germany, South Korea, and Spain do all have small oil-refining sectors, even though they are not oil producers. Jobs will be lost in these sectors as clean energy production increasingly supplants imported oil as an energy source. However, these losses should be largely counterbalanced through an increase in bioenergy refining activity—i.e., producing clean-burning ethanol from agricultural wastes and switchgrass.

5. The employment figures for clean energy investments are generated through new investments in these activities. The figures for fossil fuel employment reflect the existing levels of spending in all areas, including operations and maintenance, as well as existing investments.

6. See Pollin, Garrett-Peltier, Heintz, and Chakraborty (2015), 117–21 for a discussion of the Indonesia case as well as, more generally, the relationship between declining fossil fuel export markets for some countries and their growth prospects.

7. Mazzocchi (1993, 41). See also Les Leopold's outstanding biography of Mazzocchi, *The Man Who Hated Work and Loved Labor* (White River Junction, VT: Chelsea Green, 2007) for the historical context on the issues of a Superfund for workers and just transition.

7. Automated but Compensated?

1. For six groups at the two-digit ISCO-88 level, no information on RTI is available. These agricultural, supervisory, and residual occupational groups are also excluded by Goos et al. (2014), Autor et al. (2015), and Autor and Dorn (2013). We also have to exclude individuals in all waves for which information is available only at the one-digit ISCO level. In total, we exclude 12 percent of observations in this way.