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Robotics and the Future of Production and Work

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The use of robotics will increase productivity and has the potential to bring more manufacturing production work back to developed countries. As productivity increases, labor is likely to receive a significant share of the benefits.

KEY TAKEAWAYS

- Robot adoption will likely be a critical determinant of productivity growth and has the potential to reshape global supply chains.
- Improvements in automation technology such as robotics are poised to bring more automated manufacturing production work to developed countries, rather than offshore it to lower-wage countries.
- Most forecasts exaggerate the impact automation will have on employment. The evidence suggests structural unemployment will not increase due to automation, and labor will receive a significant share of the benefits.
- Policymakers should support—rather than resist—the development of the next production system.

INTRODUCTION

Companies around the world are increasing their use of robots. According to the International Federation of Robotics (IFR), the global average for industrial robots per 10,000 manufacturing workers grew from 66 in 2015 to 85 in 2017.[1] With integration of artificial intelligence and other improvements in robotics (e.g., better machine vision, better sensors, etc.), robotics promises to see significantly improved pricing and performance over the next decade. As a potentially new general-purpose technology, a central question is whether and how robotics will impact production processes, particularly in such globally traded sectors as manufacturing. The last major technology wave, driven by information technology, was largely decentralizing in nature, enabling the geographic distribution of far-flung supply chains to the periphery in search of cheap labor. Will the next wave of technology innovation based on robotics have the opposite effect, enabling a reshoring of manufacturing to the core? This paper examines the nature and prospects of robotics and associated production technologies, reviews the literature on their impact on spatial dynamics, reviews recent data on robotic adoption, including controlling for robot adoption rates by domestic worker compensation rates, and speculates on future trends in the spatial distribution of manufacturing.

There is both considerable excitement and trepidation about the so-called “fourth industrial revolution” and its ability to power growth around the world. (This paper eschews the term “fourth industrial revolution,” because it is a misleading and overly simplistic term—if anything, there have been at least six major production technology systems since the late 1700s, not four. The more accurate term is the “next production system.”)

While there are many important questions about the next production system, including the timing of impacts, the nature of the technologies involved, and the effects on industries, labor markets, and productivity, one critical question is how its impacts will likely differ between developed and developing economies. The short answer is that while both developed and developing economies will benefit from the next production system, developing economies will likely benefit less, in part because their lower labor costs provide less incentive to replace it with technology, and because the new production systems appear to enable shorter production runs, smaller factories, and higher productivity—all of which should enable reshoring to higher-wage nations.

As the next wave of technological innovation emerges, interest in technology’s role in international affairs appears to be growing.[2] But much of that focus is on product technology (e.g., smartphones, commercial jets, automobiles, solar panels, etc.) rather than on process technology (“machines” to improve *how* a good or service is produced) that enables automation.

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Automation is a particular kind of process technology. The term “automation” was originally coined in 1945 when the engineering division of Ford Motor Company used it to describe the operations of its new transfer machines that mechanically unloaded stamping from body presses and positioned them in front of machine tools. Today, it refers to any production process that is controlled by a machine, with little or no input from an operator in order to produce, in a highly automatic way. There are many technologies that can enable a production process to be automated, and robotics is an increasingly important one. While there is no hard and fast definition of "robotics," the term generally refers to physical machines that can be programmed to perform a variety of different tasks, with some level of interaction with the environment, and limited or no input from an operator.

Robots are key tools for boosting productivity. To date, most robot adoption has occurred in manufacturing, wherein they perform a wide variety of manual tasks more efficiently and consistently than humans. But with continued innovation, robot use is spreading to other sectors, from agriculture to logistics to hospitality. Robots are getting cheaper, more flexible, and more autonomous, in part by incorporating artificial intelligence. Some robots substitute for human workers; others—collaborative robots, or "cobots," which work alongside workers—complement them. As this trend continues, robot adoption will likely be a key determinant of productivity growth and will potentially reshape global supply chains.

THE NEED FOR FASTER PRODUCTIVITY GROWTH

The global economy is in need of a technology "shot in the arm"—of the kind the world experienced in the 1950s and early 1960s with electromechanical and materials innovations (steel, chemicals, plastics, etc.), and again in the 1990s with ICT innovations (personal computing, the Internet, broadband, etc.). Indeed, the global economy is in a productivity slump. The Conference Board found that change in gross domestic product (GDP) per person employed has slowed from 2.6 percent per year from 1999 to 2006 to around 2 percent per year from 2012 to 2014.[3] Most of this decline has occurred in developed economies: Productivity growth in the EU, Japan, and the United States fell by more than half after 2007, compared with the period from 1999 to 2006. And from 2005 to 2015, the world's poorest nations (with gross national income per capita of less than $9,000 seeing labor productivity growth of just around 3 percent annually, a relatively low rate given productivity catch-up is easier for lagging economies).

Faster productivity growth in many functions and industries that involve moving or transforming physical things will be spurred by better and cheaper robots. Robots are already driving productivity.[4] Investment in robots contributed to 10 percent of GDP growth per capita in Organization for Economic Cooperation and Development (OECD) countries from 1993 to 2016, and there is a 0.42 correlation between a country's wage-adjusted manufacturing robot adoption (see below) and growth in productivity between 2010 and 2017.[5]

Graetz and Michaels found that robot densification increased annual growth of GDP and labor productivity between 1993 and 2007 by about 0.37 and 0.36 percentage points respectively across 17 countries studied, representing 10 percent of total GDP growth—compared with the 0.35 percentage point estimated total contribution of steam technology to British annual labor productivity growth between 1850 and 1910.[6] A subsequent study by them found that investment in robots contributed 10 percent of growth in GDP per capita in OECD countries from 1993 to 2016.[7] The same study found that a one-unit increase in robotics density (which the study defines as the number of robots per million hours worked) is associated with a 0.04 percent increase in labor productivity. A study by the Institute for Employment Research found that robot adoption led to a GDP increase in Germany of 0.5 percent per person per robot over

10 years from 2004 to 2014.[8] Koch, Manuylov, and Smolka found that the introduction of industrial robots in Spanish manufacturing firms boosted output by 20 to 25 percent within four years, and reduced labor-cost share by approximately 6 percent.[9]

THE PRODUCTIVITY POTENTIAL OF THE NEXT PRODUCTION SYSTEM

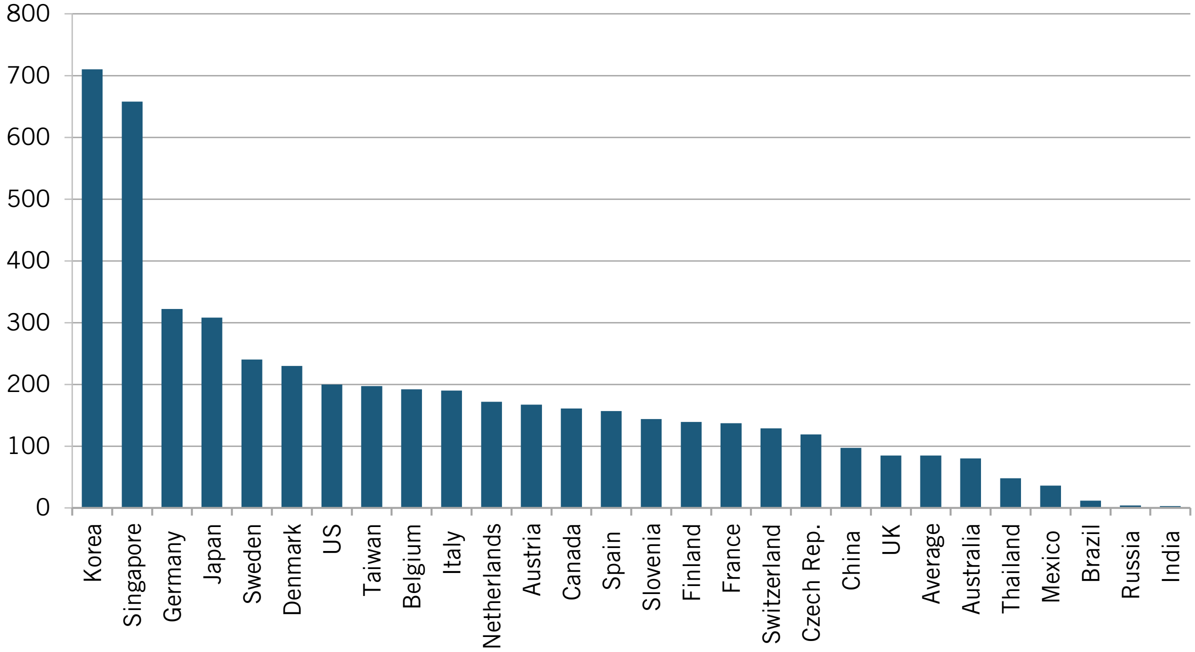
As robots and other autonomous systems continue to improve in functionality and decline in costs going forward, their likely impact on productivity will be even more significant. At least six technologies look like candidates to comprise the next innovation wave: the Internet of Things, advanced robotics, blockchain, new materials, autonomous devices, and artificial intelligence. Perhaps artificial intelligence and robotics are the most important. Artificial intelligence has many functions, including but not limited to learning, understanding, reasoning, and interaction.[10] And easy-to-program, dexterous, and relatively affordable robots could enable automation of a range of functions in agriculture, manufacturing, and services.

While these technologies are already in the marketplace, all are generally too expensive and ineffective to be widely adopted enough to drive higher rates of economy-wide productivity growth. This is why, for example, despite the excitement over "Industry 4.0" technologies, they do not appear to have been adopted on a large scale, as evidenced in part by most manufacturers in developed nations appearing to be in the very early stages of adoption.[11] Likewise, while there is considerable excitement about machine learning software systems, their current capabilities remain relatively limited—notwithstanding some promising early applications. Fully autonomous cars that are safe and sold at a price point most consumers can afford are likely at least 15 years away.[12] And fully dexterous robotic hands are not likely to be in the market before 2030, or even 2040.[13] As MIT roboticist Rodney Brooks wrote, "Having ideas is easy. Turning them into reality is hard. Turning them into being deployed at scale is even harder."[14] If these technologies really were "ready for prime time," one would expect to see higher rates of productivity growth. But, to paraphrase Robert Solow, we see the next production system everywhere except in the productivity statistics.

PATTERNS OF NATIONAL ROBOT ADOPTION

Even with these challenges, these next-production-system technologies are being developed and, in a growing array of cases, are already in use. One of these is robotics. As such, a critical question is how nations compare in robot adoption. The most commonly used metric is the number of industrial robots as a share of manufacturing workers. According to IFR, the global average for industrial robots per 10,000 manufacturing workers grew from 66 in 2015 to 85 in 2017.[15] South Korea was the world's most advanced adopter with 710 robots per 10,000 workers; Singapore, Germany, Japan, and Sweden followed. The United States ranked seventh with 200 industrial robots per 10,000 workers. Russia and India ranked last with just 4 and 3 robots per 10,000 workers, respectively. (See figure 1.)

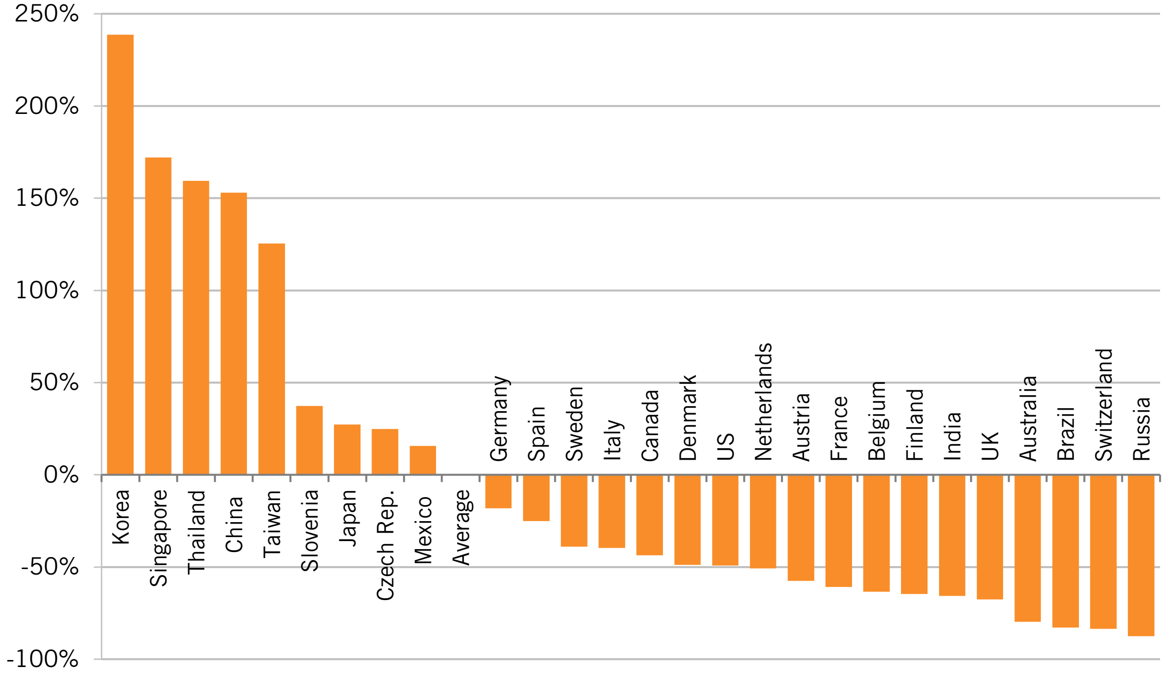
Figure 1: Robots per 10,000 manufacturing workers, 2017



There is a stronger economic case for adopting robots in higher-wage economies than in lower-wage economies because investments in robots are often justified by how much they save in labor costs. This is why the Boston Consulting Group (BCG) estimated labor cost savings from robotics are considerably lower for developing nations.[16] So, the more germane question is: Where do nations stand in robot adoption when taking wage levels into account? [17] To assess this, the estimated time of payback (in months) from installing a robot must be calculated.[18]

Comparing the ranking of expected robot adoption given differences in compensation levels to actual rates, several patterns emerge. First, East Asian nations lead, occupying six of the top seven positions in the ranking: Korea leads with 2.4 times more robots adopted than expected, while Singapore, China, Thailand, and Taiwan follow. Japan ranks seventh. In contrast, Commonwealth nations lag behind significantly, with Canada ranking 14th (44 percent below expected adoption rates), the United Kingdom 23rd (73 percent below), and Australia 24th (80 percent below). (See figure 2.)

Figure 2: Actual robot adoption rates as a share of expected robot adoption rate[19]



Overall, Europe is a laggard, with only two Eastern European countries adopting more than expected given its wage levels: Slovenia (37 percent above expected adopted rate) and the Czech Republic (25 percent above). All other EU nations had lower-than-expected adoption rates.

Among developing counties, Thailand leads with adoption rates 159 percent more than what its wage levels would predict, while China's adjusted rate is 153 percent higher, up from 104 percent greater in 2016. Mexico also outperforms, with adoption rates 16 percent higher than expected. But Brazil, India, and Russia, even with their low wages, are laggards. India's adoption is 66 percent below the expected rate, Brazil's is 83 percent below, and Russia's 88 percent below. Finally, the United States is significantly behind, ranking 16th, with adoption rates 49 percent below expected.

WHY DO SOME COUNTRIES LEAD IN ROBOT ADOPTION?

It is not clear why some countries lead and others lag. Wage levels are not the only factor. Robot adoption differs by industry, with the automobile industry generating the largest demand. Depending on the country, the industry accounts for 30 to 60 percent of total robot adoption. Yet many of the lagging nations—including Brazil, Canada, France, Germany, Italy, Russia, Spain, Sweden, and the United States—have robust automobile industries relative to the size of their manufacturing economies.[20] And China scores well in overall robot adoption despite having a relatively small automotive sector (on a per-GDP basis) compared with the rest of these nations.

Acemoglu and Restrepo found a modestly positive correlation between robot adoption and higher ratios of middle-aged workers, with the logic being that less robot adoption reflects a relative scarcity of middle-aged workers—who tend to have higher wages and often can be replaced by robots.[21] But the correlation is not strong enough to explain the large differences, even with the wage factor included in the analysis.

Cultural attitudes may play a role. Lee and Sabanovic found that cultural attitudes play a role in robot adoption rates, with South Koreans having more favorable views of robots in the economy than Americans.[22] Some countries appear to welcome robots—Japan even has an annual "Robot Award"—while others embrace narratives of Terminator-like machines destroying jobs.[23] There is a modest positive correlation of 0.20 between the countries' wage-adjusted industrial robot adoption rates and the degrees to which countries' residents believe more emphasis should be placed on the technology in the future.[24]

Industrial relations may also play a role. For example, some argue that one reason South Korea is so far ahead is its industrial unions are quite militant, engaging in strikes and other work stoppages on a fairly regular basis, particularly in the auto industry.[25] In response, many of the "chaebols" (large, usually family owned, business conglomerates) have turned to robotics as a way to ensure more production stability.

Government policies also appear to play a key role. Some of the leading countries have established national strategies to support robotics innovation and adoption. In 2014, Japan established a goal to realize a "new industrial revolution driven by robots," while South Korea enacted its Intelligent Robot Development and Promotion Act.[26] Japan has also established public-private robotics research and development (R&D) partnerships, which one study found were highly effective in spurring robot development.[27] In contrast, the United States lacks a national robotics strategy.

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Some of the leaders, particularly South Korea, Taiwan, and Japan, also have robust public programs to help manufacturers—particularly small and medium-sized enterprises—adopt advanced technologies, and some nations have proactive tax policies to provide incentives for advanced technology adoption, including robotics.[28] In Singapore, for example, firms can expense in the first year all investments in computers and prescribed automation equipment, robots, and energy-efficiency equipment.[29] South Korea provides an investment tax credit for new equipment, while Japan and Slovenia provide accelerated depreciation on new equipment.[30] In contrast, some nations, such as the United States and United Kingdom, have less generous tax treatment of capital expenditures and exhibit lower levels of capital expenditures by manufacturers.[31]

China appears to be in a class of its own, with its national and provincial governments committing massive amounts of money toward subsidizing robotics adoption. China's Robotics Industry Development Plan (2016–2020), part of its Made in China 2025 initiative, promotes domestic robot production and sets a goal of expanding robot use by such companies tenfold by 2025. As a result, many provincial governments are providing generous subsidies for firms to buy robots—although the accuracy of reported figures is potentially dubious, largely because the numbers are so high and provincial governments have strong incentives to inflate reported numbers in order to gain favor with the national government. Guangdong province will supposedly invest 943 billion yuan (approximately $135 billion) to help firms carry out "machine substitution." Likewise, the provincial government of Anhui has stated it will invest 600 billion yuan (approximately $86 billion) to subsidize industrial upgrading of manufacturers in its province, including through robotics.[32] Nonetheless, China appears to provide greater subsidies for robot adoption than any other nation. As a result, if China's and South Korea's respective growth rates continue at the same pace achieved between 2016 and 2017, then by 2026 China will lead the world with the highest number of industrial robots as a share of its industrial workers.

GLOBAL SUPPLY CHAINS AND RESHORING?

Past major waves of technological innovations have had different spatial impacts, favoring some nations more than others. The next production system will likely be no different and will play out in two areas: productivity and international competitiveness.

Over the last 40 years, improvements in global transportation and information technology have enabled significant offshoring of supply chains to low-wage countries. And even though the productivity of workers in low-wage countries is lower than in higher-wage countries for many industries and functions, the low wages more than compensate for lower productivity and increased transportation costs. This process began with the well-documented offshoring of low-technology, low-value-added, labor-intensive manufacturing industries such as textiles, apparel, and luggage to East Asian and Latin American countries starting in the mid-1970s. And the trend has continued. Imports of wood furniture, for example, increased from 38 percent in 2000 to 68 percent of the U.S. market in 2008.[44] Today, American producers account for just 1 percent of the U.S. luggage market and 1.7 percent of the outerwear apparel market.

This may change as automation technology, including robotics—which is available anywhere in the world—improves and allows more work in advanced countries to be automated. So why won't low-wage countries install it at the same rates as higher-wage countries? The answer is, absent government subsidies, it makes less economic sense to install robots in these locales. For example, assuming a $250,000 initial investment in a robot that replaces two workers (one on each shift) in the United States, where annual total compensation for the average manufacturing worker is $72,000, the payback period (the time it takes for savings to exceed costs) would be less than one year.[33] But in Mexico, where the average compensation is $14,000, the payback is much longer: eight years and four months. And in the Philippines, where average compensation is just $4,200, payback is longer than 30 years. Given that most firms require paybacks of less than four or five years, this suggests a very slow rate of robot penetration in low-wage developing nations. This is why BCG estimated the labor cost savings from robotics to be considerably lower for developing nations.[34]

However, robot costs are declining and performance is improving. Will this make a difference? The Boston Consulting Group predicted a percent reduction in prices and a 5 percent improvement in performance in robotics per year over the next decade.[35] If robotic innovation advances rapidly, to where the cost of a robot falls to about $50,000, paybacks in emerging markets will begin to make more economic sense. In Mexico, that period is one year and nine months. But in the Philippines, the payback is still long: eight years and four months. Moreover, such improvements may not be realized.[36] This suggests lower-wage nations will lag in their ability to take advantage of these technologies. This trend could widen productivity and income differences with developed nations.

This is why it is likely higher-wage nations will get more of a productivity boost from these technologies than lower-wage ones. In its estimates of the impact of labor displacement by automation between now and 2030, the McKinsey Global Institute found that higher income nations will have higher rates of labor displacement because the higher wages make it more economical to invest in labor-replacing technology.[37] While installing some of these technologies will be less expensive in lower income nations, the relative price of the technology compared with labor costs will still be higher than in higher-wage nations. As such, the payback time for the investments in terms of labor savings will be considerably longer in lower-wage nations.

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This could mean long-standing centrifugal forces, in which commoditized production has spun out of rich nations to low-cost nations, could slow—or even reverse—thereby generating centripetal forces wherein at least some work comes back to serve local markets. In manufacturing, smart manufacturing systems will enable more flexible production and shorter production runs. The application of information and communication technology to every facet of manufacturing is reshaping modern manufacturing. Smart manufacturing is being driven by many technologies, including computer aided design software, cloud computing, the Internet of Things, sensor technologies, 3D printing, robotics, data analytics, machine learning, and wireless connectivity. This digitalization is changing how products are designed, fabricated, operated, and serviced, just as it is transforming the operations and processes of manufacturing supply chains.

In other words, current manufacturing systems largely enable either high-volume, low-mix output (e.g., producing large quantities of the same unit; mass production) or low-volume, high-mix output (e.g., producing smaller quantities of different units; batch production). The latter are often located in lower-wage countries. But convergence of digital technologies and manufacturing increasingly leads to a new production paradigm: a high-volume, high-mix approach that enables cost-efficient production in smaller factories more evenly distributed around the globe to serve local markets. Indeed, Rauch, Dallasega, and Matt, engineering professors at the Free University of Bozen-Bolzano, have argued that these emerging technologies will enable more decentralized and geographically dispersed manufacturing systems.[38] In a survey of 238 Citigroup clients, 70 percent believed automation would encourage companies to consolidate production and move their manufacturing closer to home.[39] Krenz, Prettner, and Strulik estimated that, within manufacturing sectors, an increase by 1 robot per 1,000 workers is associated with a 3.5 percent increase in reshoring activities.[40] And an OECD report finds that, to date, robotics slows down—and in some cases, stops—offshoring and is thus a key to helping keep manufacturing in developed economies.[41]

ROBOTS AND JOBS

What about job loss? There has been considerable ink spilled warning of the coming job-destruction tsunami from the next production system. A widely cited study by Oxford University researchers Carl Benedikt Frey and Michael A. Osborne set the tone in 2013 when it claimed that 47 percent of U.S. employment was at risk of job loss from new technology.[42] Yet, these and similar studies warning the next production system will lead to massive job loss and potentially high levels of structural unemployment suffer from a number of mistakes.

First, these studies assume we are heading to a transformative fourth industrial revolution the likes of which the world has never seen, leading to rapid productivity growth. Berg, Buffie, and Zanna reflected this view when they wrote, "The premise of this paper is that we are in the midst of a technological inflection point, a new 'machine age' in which artificial intelligence and robots are rapidly developing the capacity to do the cognitive as well as physical work of large fractions of the labor force."[43] The McKinsey Global Institute estimated that, compared with the Industrial Revolution of the late 18th and early 19th centuries, artificial intelligence's disruption of society is happening 10-times faster and at 300 times the scale—which means roughly 3,000 times the impact.[44]

There are two main problems with such speculations. First, they are just that: grounded in little evidence and completely unbound from historical analysis. Moreover, many estimates of exponential growth, such as the McKinsey estimate, refer to adoption rates of particular technologies, such as mobile phones, to extrapolate to overall rates of technological innovation and productivity growth rates. Moreover, there is no evidence provided that the societal pace of change for technology is 10-times faster now than two centuries ago, much less faster at all. These are all premised on adoption rates of technologies such as mobile phones and Internet adoption. But what about the much slower adoption rates of other information technologies such as digital signatures and biometrics? In fact, Bloom, Jones, Van Reenen, and Webb found the productivity of R&D has been declining, thereby making it harder to get innovation.[45]

Second, many studies look only at the impact of robots on jobs in the region adopting them, and not surprisingly, usually find that regions with higher robot adoption have either declining employment growth or slower-than-economy-wide employment growth. For example, Chiacchio, Petropoulos, and Pichler have studied the impact of industrial robots on employment in 116 regions in six EU-15 nations and found that regions with a faster rate of robot adoption had lower rates of labor force growth.[46] But this is not surprising, as regions that specialize in manufacturing will likely experience slower employment growth if manufacturing productivity grows faster than non-manufacturing productivity. The relevant question is, does higher productivity in an overall economy lead to lower employment growth? There was, in fact, a correlation of 0.15 between productivity growth and total growth in labor hours in EU-15 nations from 1997 to 2015, suggesting productivity does not have negative consequences for employment growth.[47]

Acemoglu and Restrepo focus on local labor markets in the United States, but have also attempted to measure the impacts of industrial robots on all labor markets.[48] They found that robot adoption leads to fewer net jobs as expected. However, its impacts are quite small. They estimated the number of U.S. jobs lost due to robots since 1990 is somewhere between 360,000 and 670,000—quite a small number in an economy with over 130 million jobs. Moreover, when the researchers included a measure of the change in computer usage at work, they found a positive effect.

Moreover, a number of other studies find no evidence for job loss. In an analysis of industrial robots on employment in German labor markets between 1994 and 2014, Dauth, Findeisen, Suedekum, and Woessner found that the adoption of industrial robots had no effect on total employment in local labor markets specializing in industries with high robot usage.[49] In an analysis of the impact of automation on jobs in Europe, Gregory, Salomons, and Zierahn found that while technology-based automation displaces jobs, "it has simultaneously created new jobs through increased product demand, outweighing displacement effects and resulting in net employment growth."[50] As discussed, Koch, Manuylov, and Smolka found that adoption of robots in manufacturing firms in Spain has led to net job creation of about 10 percent.[51]

It is likely the emergence of the next production system and improvement in robotics technology will increase both productivity and labor-market churn. But higher labor-market-churn rates are not the same as higher unemployment rates.

Firm-level studies that show job loss from robots find results that are opposite from virtually all the studies that have examined this at the macroeconomic level, which find that productivity growth has no negative effect on employment, at least in the moderate term. There are a number of reasons why job impacts, even at the industry level, are likely to be minimal. Mayer found a higher share of robots helps economies' manufacturing sectors gain global market share.[52] Because of this gain, the correlation between robot use and manufacturing as a share of national employment is negative, albeit only slightly.[53] Conversely, it is countries such as Canada, the United States, and the United Kingdom—those with low rates of manufacturing adoption and automation—that have seen the highest rates of manufacturing job loss over the past two decades.[54] There are three reasons countries can lose manufacturing employment: slower growth in manufacturing consumption relative to non-manufacturing consumption, higher manufacturing productivity growth relative to non-manufacturing, and reduced output from loss of international competitiveness (e.g., manufacturing exports growing slowly or declining while imports grow). In the U.S. case, Information Technology and Innovation Foundation (ITIF) estimated that over half of the very steep loss of manufacturing jobs between 2000 and 2011 (over 33 percent) was caused by trade (manufacturing imports increasing faster than exports), and less than half by faster manufacturing productivity.[55]

Second, companies invest in process innovations to cut costs (and sometimes to improve quality). They pass a significant share of those savings to consumers in the form of lower prices (with some going to workers in the form of higher wages and others to shareholders via higher profits). But the savings are not buried, they are recycled—and this added purchasing power is spent or invested, thereby creating new jobs. This is why OECD has found, "Historically, the income-generating effects of new technologies have proved more powerful than the labor-displacing effects: technological progress has been accompanied not only by higher output and productivity, but also by higher overall employment."[56] Likewise, in a study of 24 OECD nations, Tang found that, "at the aggregate level there is no evidence of a negative relationship between employment growth and labour productivity growth."[57] Likewise, in its 2004 *World Employment Report,* the International Labor Organization found strong support for simultaneous growth in productivity and employment in the medium term.[58] Van Ark, Frankema, and Duteweerd also found strong support for simultaneous growth in per-capita income, productivity, and employment in the medium term.[59]

Third, many of the studies looking at the impacts of technology on jobs significantly overstate the likelihood of job loss from new technology, in part because they focus on jobs rather than discrete tasks. Some tasks might be automatable, but the overall job might not be. For example, Arntz, Gregory, and Zierahn have argued the Oxford study overstates that share of automatable jobs by "neglecting the substantial heterogeneity of tasks within occupations as well as the adaptability of jobs in the digital transformation." They found that when controlling for these factors, the automation risks of U.S. jobs drops from 38 percent to 9 percent.[60]

To be sure, it is likely the emergence of the next production system and improvement in robotics technology will increase both productivity and labor-market churn, as more workers are likely to lose their jobs due to technological displacement.[61] But higher labor-market-churn rates are not the same as higher unemployment rates because, historically, higher churn rates are not associated with higher unemployment rates. For example, in the 1990s, the labor market churn rates (the share of workers losing their jobs due to establishments closing or downsizing) was about 25 percent higher than in the prior decade, but overall unemployment was low.[62]

Higher levels of churn only lead to higher levels of unemployment if the dislocated workers do not reenter the labor market in a timely manner.

ROBOTS, WAGES, AND INEQUALITY

Even if there is little reason to believe there will be significantly higher rates of structural employment from the next production system, a number of scholars have argued that it will lead to increased income inequality and possible immiseration for many workers. But these studies suffer from significant methodological and logical flaws, thereby rendering their conclusions flawed.

A leading example of this work is the report by Berg, Buffie, and Zanna, "Should We Fear the Robot Revolution? (The Correct Answer is Yes)." Their finding is a bit surprising given that, in a prior article for the International Monetary Fund's *Finance & Development Journal*, they stated that "technology does not seem to be the culprit for the rise in inequality in many countries [which is] concentrated in a very small fraction of the population."[63] Perhaps they think this time will be different. Their study, however, is a prime example of Kenneth Boulding's famous quote that while mathematics brought rigor to economics, and it also brought mortis.[64] The authors created "four models of the short and long-run effects of robots on output and its distribution in a family of dynamic general equilibrium models." They found that in all four models, robots increase productivity but reduce wages. But the assumptions of models is unrealistic. For example, their first model had robots capable of doing all jobs, something that even the most enthusiastic believer in the power of the next production system would argue is unrealistic.

Overall, this and related studies make three major methodological errors and logical mistakes. The first is they do not adequately account for second-order effects and the fact that when organizations use robotics to automate and eliminate work, they do so to reduce costs. Acemoglu and Restrepo wrote that automation technologies "reduce overall labor demand because they are displacing workers from the tasks they were previously performing."[65] Even when this is true, few if any organizations spend more on robots than they save in labor costs (unless they are using robots to boost quality). And those labor-savings costs are not buried. They are spent—and that spending creates jobs. This is why, as ITIF found, from 1850 to 2015, despite some decades with significant occupational churn from automation technology (e.g., the tractor, automatic elevator, automatic telephone switch, etc.), employment grew at the same rate as the labor force.[66] As Autor wrote, “Automation does indeed substitute for labor—as it is typically intended to do. However, automation also complements labor, raises output in ways that lead to a higher demand for labor, and interacts with adjustments in labor supply. Even expert commentators tend to overstate the machine substitution for human labor and ignore the strong complementarities between automation and labor that increase productivity, raise earnings and augment demand for labor.”[67]

In some of the models, researchers accept that there are savings but then assume that the lion’s share of the savings are captured by “capital” and few go to labor either in the form of higher wages or lower prices. But this is illogical, and history suggests it is wrong. The only way capitalists can capture the majority of the gains from automation is if limited competition in the market allows them to capture most or all of the savings as profits. If this is true, then why over the last 40 years, when labor productivity has more than doubled, are corporate profits essentially unchanged? The answer is competitive markets limit the ability of companies to capture most of the gains from productivity as profits, especially over the medium to long term. Moreover, no one has made a convincing case that there is anything about the next production system that would lead to massive monopolization of the global economy in virtually all sectors. Competition, especially backed up by national antitrust authorities, is not likely to die.

In some models, researchers accept that there are savings but then assume that the lion’s share of the savings are captured by “capital.” This is illogical, and history suggests it is wrong.

Second, Berg, Buffie, and Zanna only looked at first-order effects, so their models find that unemployment goes up as automation makes tasks more efficient. Their models then determine the wage rate on the basis of supply and demand, which leads to the illogical finding that increased labor output (which all four of their models find) leads to decreased labor income and a larger share of income going to capital. Because they focused on allocation efficiency, rather than on productive efficiency, they assumed less demand for labor with the same supply, and therefore that the price of labor must fall. The wrote, “At first, the real wage is likely to fall in absolute terms, even as the economy grows.”[68]

There are several things wrong with this framing. First, the supply of labor does not fall once second-order effects are taken into account. In other words, productivity leads to lower prices, which leads to increased demand and therefore restores labor demand. Second, it is vast oversimplification to suggest the real price of labor is a function solely, or even principally, of the relationship between supply and demand of labor. If the Keynesian revolution told us one thing it was that the classical-economics view that labor prices are a function of supply is wrong; wage rates are in fact sticky, which is why, for example, wages generally to do not fall during recessions. Institutional factors such as the minimum wage, employer-labor contracts, unionization, and the need for companies to maintain the goodwill of their workers, all mean that even if unemployment rates were to go up from technology-based automation (which is not likely to happen, at least during non-recessionary periods), wage rates would not fall. Therefore, as the U.S. Bureau of Labor Statistics has found, when firms reduce costs through automation, those savings raise wages or lower prices, or both.[69] Likewise, Graetz, and Michaels, in a review of the economic impact of industrial robots across 17 countries, found that robots increase wages while having no significant effect on total hours worked.[70]

Finally, many of the claims that the next production system will boost inequality point to the decline in labor's share of national income in the United States as evidence that technology has harmed labor and helped capital—and that this decline will accelerate going forward. But this view reflects a serious misreading of national income accounts. First, when looked at over the longer term, and when using net income instead of gross, there has been almost no decline in the share of U.S. national income going to labor. Gross domestic income (GDI) includes depreciation (what the U.S. Bureau of Economic Analysis terms "capital consumption"), which amounts to about 16 percent of GDI. It also includes business taxes, which are around 7 percent of GDI. When these are pulled out, labor's share of net income was around 70 percent of net domestic income in 2017. In 1949, this share was 69 percent.[71] It is true that labor's share rose slightly from 1940 to the early 1990s to around 73 percent and has fallen slightly since then. But that decline was not mostly from the rise of corporate profits, but rather from the rise of housing income and proprietor income. When looking at GDI, the share of labor fell by 2.6 percentage points from 1985 to 2017. But the share going to net interest and corporate profits actually declined. So, where did the income go? The share of GDI going to rental income increased 3.1 percentage points, while consumption of fixed capital increased by 1 percentage point. In other words, the fall in the share of labor income had nothing to do with capital becoming more important than labor. It had more to do with housing becoming more important than labor, with the demographic forces pushing up demand for housing, and government zoning rules limiting supply.

Many of the claims that the next production system will boost inequality point to the decline in labor's share of national income as evidence that technology has harmed labor and helped capital—and that this decline will accelerate. But this view reflects a serious misreading of national income accounts.

These models hypothesize a growing inequality between capital and labor. Some argue instead that the major growth on inequality from robots will be within labor. It appears the automation impacts from the next production system will be significantly larger for lower-wage and lower-skill occupations. To assess this, the risks of automation by occupation were compared to occupational wage levels and years of schooling needed for the occupation using two data sets: the Oxford study by Osborne and Frey, and a study by ITIF. The correlation between the average wage of an occupation and its risk of automation is negative and quite large for both data sets (-0.59 for Oxford, -0.52 for ITIF). The correlation of average years of schooling and risk of automation is also negative and large (-0.64 for Oxford, -0.51 for ITIF).[72] Similarly, the White House Council of Economic Advisors also used the Oxford data and found 83 percent of jobs making less than $20 per hour would come under pressure from automation, as compared with 31 percent of jobs making between $20 and $40 per hour, and just 4 percent of jobs making above $40 per hour.[73] This is not a reflection of the actual wages of the jobs (in fact, the incentive to automate jobs is greater the higher the wage level.) Rather, it refers to the kinds of jobs and tasks that are most amenable to automation (routine, low-productivity jobs that pay poorly). OECD estimated 44 percent of American workers with less than a high-school degree hold jobs made up of highly automatable tasks, while only 1 percent of people with a bachelor's degree or higher hold such a job.[74]

Many will argue that these future occupational automation patterns are problematic, and cause individuals with lower incomes to be more at risk. While true, if this occupational impact pattern occurs, the occupational profile of advanced economies will by definition shift to one with a higher share of middle- and upper-wage jobs (as lower-wage jobs are automated at higher rates and therefore employ fewer people). This would result in relatively fewer lower-paying jobs and more higher-wage jobs—a plus for many workers now employed in occupations whose wages remain low and stagnant. The reason behind employment shifting to more middle- and higher-wage jobs is not necessarily intuitive. As more lower-wage jobs become automated, the prices of the goods and services still produced by the lower-wage workers also declines in relative terms (were there no associated cost savings, firms would have no incentive to employ technology to boost productivity). These savings result in consumers across the income spectrum spending more on other goods and services—with the employment generated by this added production in industries with low-, middle-, and high-wage jobs. Thus, added demand creates more middle- and higher-wage jobs.

Moreover, the fact that many workers in low-wage jobs are overqualified suggests that at least some workers now holding these jobs have enough skills to move relatively easily into higher paying, moderately-skilled jobs.[75] In most developed nations, there is a modest share of workers with college degrees who are employed in jobs that do not require one. Although some are in these occupations by choice, many others settle for these positions because there are simply not enough available jobs that require a college education. On average, these workers should have an easier time transitioning to newly created middle-wage jobs than workers with less education and skills. To be sure, this doesn't mean it will be easy for all dislocated workers to transition to better jobs. For them, there is an urgent need to improve policies and programs to boost skills, especially of workers in low-wage jobs.

CONCLUSION

The next production system will be a welcome development for a global economy that is experiencing lagging investment and productivity growth. This next technology wave holds the potential to lead to a virtuous cycle of increased investment, faster rates of productivity and wage growth, and more spending. It appears likely that developed nations will benefit more, both from higher rates of investment and productivity growth, and from production systems that are more conducive to localized production. Moreover, notwithstanding some studies that suggest the next production system will lead to higher structural unemployment and reduced labor incomes, the evidence and logic suggests structural unemployment will not increase, and labor will receive a significant share of the benefits (akin to historical shares). Policymakers should therefore support—not resist—the development of the next production system.

About the Author

Robert D. Atkinson is the founder and president of ITIF. Atkinson's books include Big is Beautiful: Debunking the Myth of Small Business (MIT, 2018), *Innovation Economics: The Race for Global Advantage* (Yale, 2012), and *The Past and Future of America's Economy: Long Waves of Innovation That Power Cycles of Growth* (Edward Elgar, 2005). Atkinson holds a Ph.D. in city and regional planning from the University of North Carolina, Chapel Hill, and a master's degree in urban and regional planning from the University of Oregon.

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