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Robots and International Economic Development

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The next production revolution will be a boon for a global economy that is sputtering and experiencing lagging growth and investment. This new technology wave should lead to a virtuous cycle of increased investment, higher productivity, more spending, and more investment.

KEY TAKEAWAYS

- Improving productivity in functions and industries that involve moving or transforming physical things will depend on much better and cheaper robots.
- There is a stronger economic case for adopting robots in higher-wage economies than there is in lower-wage economies, because investments in robots often are justified by how much they can save in labor costs.
- The most commonly used metric of robot adoption is the number of industrial robots as a share of manufacturing workers. On that score, Korea, Singapore, Germany, Japan, and Sweden are the world leaders.
- On a wage-adjusted basis, assessing actual robot adoption rates as a share of expected adoption rates, East Asian nations lead: The top five countries are Korea, Singapore, Thailand, China, and Taiwan.
- It is not clear why some nations lead and others lag in wage-adjusted robot adoption. One explanation is that robot adoption differs by industry. Cultural attitudes also may play a role. But government policy appears to be a key factor.
- All nations stand to benefit from the next production revolution, but to maximize their gains developing nations must carefully avoid innovation-hampering tax and regulatory policies, while facilitating enterprise adoption of these systems.

INTRODUCTION

As the next wave of technological innovation emerges, interest in technology's role in international affairs appears to be growing.[1] But much of that focus has been on product technology (e.g., smartphones, commercial jets, autos, solar panels), rather than process technology ("machines" to improve *how* a good or service is produced).

Automation is a particular kind of process technology. The term 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 the 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, but robotics is an increasingly important one. While there is no hard-and-fast definition of a "robot," 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. Whether a robot looks like a human is irrelevant to whether it is a robot.

Robots are key tools for boosting productivity. To date, most robot adoption has occurred in manufacturing, where there are robots designed to perform a wide variety of manual tasks more efficiently and consistently than humans. But with continued innovation, robot use is spreading to many other sectors too, from agriculture to logistics to hospitality. Robots are getting cheaper, more flexible, and autonomous, in part by incorporating artificial intelligence. Some robots will substitute for workers; others (cobots) will complement workers. As this trend continues, robot adoption will be a vital determinant of national economic progress and potentially will reshape global supply chains.

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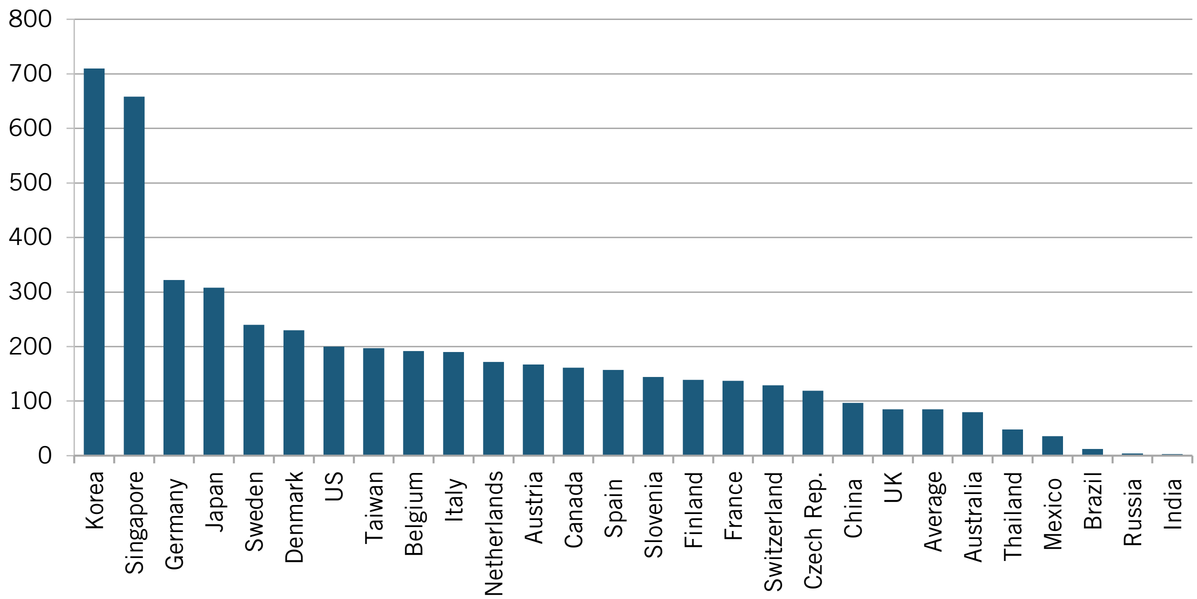
Boosting robot adoption will be critical because both the U.S. economy and the global economy are suffering from a productivity slump. The Conference Board has found that change in gross domestic product (GDP) per person employed slowed in from 2.6 percent per year from 1999 to 2006 to around 2 percent per year from 2012 to 2014.[2] Most of this decline occurred in advanced nations: Productivity growth in the EU, Japan, and the United States fell by more than half after 2007 compared with 1999 to 2006.

Improving productivity in many functions and industries that involve moving or transforming physical things will depend on much better and cheaper robots. To be sure, robots are already driving productivity.[3] Investment in robots contributed 10 percent of growth in GDP per capita in Organization for Economic Cooperation and Development (OECD) countries from 1993 to 2016.[4] But we have barely scratched the surface of their potential because of limitations in functionality and costs.

PATTERNS OF NATIONAL ROBOT ADOPTION

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 the International Federation of Robotics (IFR), the global average for industrial robots per 10,000 manufacturing workers grew from 66 robots in 2015 to 85 in 2017.[5] South Korea was the world's most advanced adopter of industrial robots in 2017, 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. (See figure 1.)

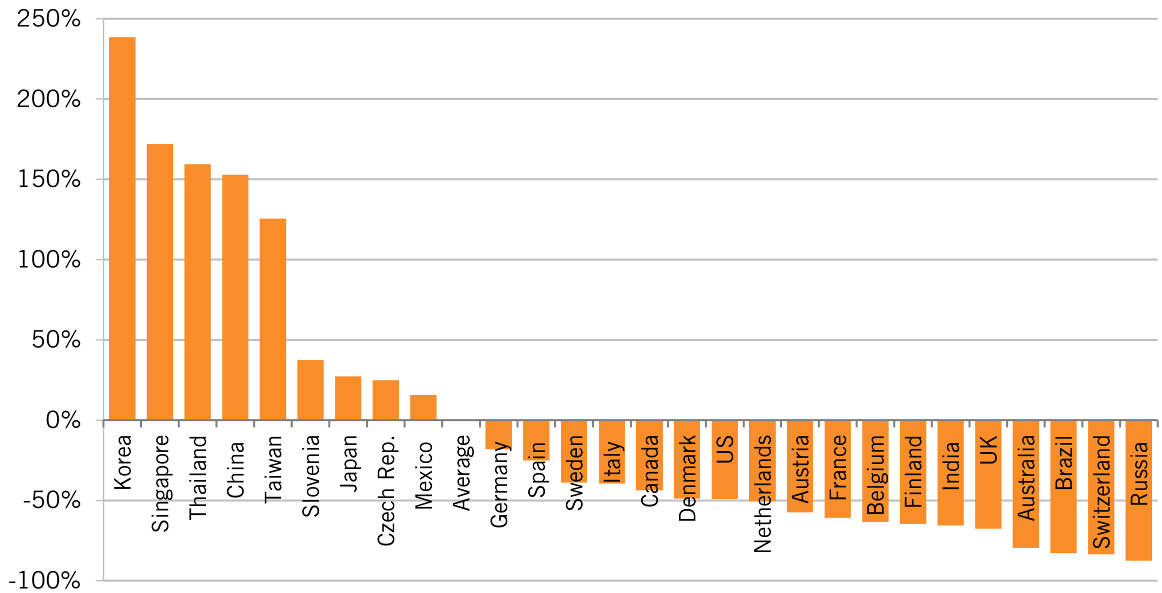
Figure 1: Robots per 10,000 manufacturing workers, 2017[6]



There is a stronger economic case for adopting robots in higher-wage economies than there is in lower-wage economies because investments in robots often are justified by how much they can save in labor costs. This is why the Boston Consulting Group (BCG) estimated that the projected labor cost savings from robotics are considerably lower for developing nations than for developed ones.[7] So, the more germane question is: Where do nations stand in robot adoption when we take wage levels into account? To assess this, the Information Technology and Innovation Foundation (ITIF) identified average total compensation for manufacturing workers in each country and calculated the estimated time of payback (in months) from installing a robot.[8]

Comparing the ranking of expected robot adoption given differences in compensation levels with actual rates, several patterns emerge. The first is that, on a wage-adjusted basis, East Asian nations lead the world, occupying six of the top seven positions in the ranking; Korea leads with 2.4 times more robots adopted than expected, and 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 rate as a share of expected robot adoption rate[9]



Overall, Europe is a laggard, with only two countries adopting more than expected given 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.

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Among developing nations, Thailand leads with adoption rates 159 percent more than that which 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 NATIONS LEAD IN ROBOT ADOPTION?

It is not clear why some nations lead and others lag in wage-adjusted robot adoption. To be sure, wage levels are not the only factor to weigh in assessing adoption rates. Robot adoption differs by industry, with the automobile industry generating the largest demand for industrial robots. 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.[10] And China scores well in overall robot adoption despite having a relatively small auto 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-wage workers—who tend to have higher wages and often can be replaced by robots.[11] But the correlation is not strong enough to explain the large differences that ITIF's analysis finds—and the wage factor is included in the analysis here.

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 do.[12] Some nations appear to welcome robots: Japan has an annual "Robot Award," while others embrace narratives of "terminator-like" machines destroying jobs.[13] Robot adoption is correlated with overall societal views of technology. Using the World Values Survey question of whether a nation's residents think there should be more emphasis on the technology in the future, there is a modest positive correlation of 0.20.[14] Many of the economies that are lagging in their relative rates of robot adoption appear to have significant portions of their populations, or at least significant shares of their elites, viewing robots as unsafe job killers.

However, government policy appears to play a key role. Some of the leading nations have established national goals and strategies to support robotics innovation and robot adoption. For example, in 2014, Japan established a goal to realize a "new industrial revolution driven by robots," while Korea enacted its Intelligent Robot Development and Promotion Act.[15] Japan also has established robotics technology public-private research and development (R&D) partnerships, which one study has shown to be very effective in spurring robotic development.[16] In contrast, the United States lacks a national robotics strategy.

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Some of the leaders, particularly Korea, Taiwan, and Japan, also have robust public programs and institutes that help their manufacturers—particularly small and medium-sized enterprises—adopt advanced technologies, including robotics.[17] Some nations have proactive tax policies to provide incentives for advanced technology adoption, also including robotics. In Singapore, for example, firms can expense in the first year all computers and prescribed automation equipment, robots, and energy-efficient equipment.[18] In addition, companies in manufacturing and engineering services industries may receive investment allowances for projects in addition to depreciation allowances. Korea provides an investment tax credit for new equipment, while Japan and Slovenia provide accelerated depreciation on new equipment.[19] 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.[20]

China appears to be in a class of its own, with its national and provincial governments committing massive amounts of money to subsidize adoption of robots and other automation technology. China's Robotics Industry Development Plan (2016–2020) set a goal of expanding robot use 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 perhaps dubious, as their sizes defy comprehension. For example, Guangdong province supposedly will invest 943 billion yuan (approximately $135 billion) to help firms carry out "machine substitution."

Likewise, the provincial government of Anhui has stated it will be investing 600 billion yuan (approximately $86 billion) to subsidize industrial upgrading of manufacturers in its province, including through robotics.[21] To put this in perspective, it is the equivalent on a per-GDP basis of the United States investing $4 trillion. Nonetheless, China appears to provide greater subsidies for robot adoption than any other nation, both in absolute and per-robot terms. As a result, if China and South Korea's respective growth rates continue at the same pace they achieved from 2016 and 2017, then by 2026, China will overtake Korea as the nation with the highest number of industrial robots as a share of industrial workers.

GLOBAL SUPPLY CHAINS AND RESHORING?

Over the last 40 years, improvements in global transportation and information technology have enabled significant offshoring of supply chains to low-wage nations. And even though productivity of workers in low-wage nations is lower than in higher-wage nations 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. Today, American producers account for just 1 percent of the U.S. luggage market and 1.7 percent of the outerwear-apparel market. And the trend has continued. For example, imports of wood furniture increased from 38 percent in 2000 to 68 percent of the U.S. market in 2008.[22]

It is possible that this may change going forward as automation technology, including robotics, improves and allows more work in advanced nations to be automated. But automation technology, including robotics, is available anywhere in the world. So why won't low-wage nations install it at the same rates as higher-wage nations? The answer is, absent granting government subsidies—as China is doing—it makes less economic sense to install robots in these nations. Assuming a $250,000 initial investment in a robot that replaces two workers (one on each shift), the payback in the United States, where annual total compensation for the average manufacturing worker is $72,000, is in less than one year.[23] 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 the 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.

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However, robot costs are declining and performance is improving. Will this make a difference? BCG has estimated a 20 percent reduction in prices and a 5 percent improvement in performance in robotics over the next decade. However, even this pace is not fast enough to seriously move the needle for investment returns in low-wage nations. But if robotic innovation advances very rapidly, to where the cost of a robot falls to say $50,000, the paybacks in emerging markets begin to make more economic sense: In Mexico, to one year and nine months, and in the Philippines to eight years and four months. But such improvements are unlikely.[24]

This suggests that even with rapid improvement in robotics, lower-wage nations will lag behind in their ability to take advantage of these and related technologies, which could widen productivity and income differences with developed nations.

This could mean that long-standing commoditized production previously spun out of rich nations to large, production locations in low-cost nations serving global markets could now slow and even reverse, generating centripetal forces wherein at least some of that work starts to come back to serve local markets. In manufacturing, smart manufacturing systems will enable more-flexible production and economically produced 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 the advent and maturation of many technologies, including high-performance computing-powered computer-aided design and engineering software; cloud computing; the Internet of Things; advanced sensor technologies; 3D printing; industrial robotics; data analytics; machine learning; and wireless connectivity that better enables machine-to-machine communications. This digitalization of manufacturing is changing how products are designed, fabricated, used, operated, and serviced post-sale, just as it's transforming the operations, processes, and energy footprint of factories and the management 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 nations. But convergence of digital technologies and manufacturing increasingly enables a new production paradigm: a high-volume, high-mix approach that will enable cost-efficient production in smaller factories more evenly distributed around the globe to serve local markets. Indeed, Rauch, Dallasega, and Matt have argued that these emerging technologies will enable more decentralized and geographically dispersed manufacturing systems.[25] This could enable more reshoring of work now located in lower-wage developing nations.

ROBOTS AND JOBS

What about job loss? The emergence of the next production revolution, which will include better and cheaper robots, will increase both productivity and labor-market churn, as more workers are likely to lose their jobs due to technological displacement.[26]

However, as Mayer has shown, a higher share of robots help economies' manufacturing sectors gain global market share.[27] Because of this gain in output, the correlation between robot use and manufacturing as a share of employment is negative, but only slightly.[28] Conversely, it is actually 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.[29] Companies that fail to invest in the newest and most efficient production systems lose their competitiveness and risk going out of business. Entire industries can go into blight, with everyone therein losing their jobs. Companies that leverage the latest automated production systems may displace some workers, but if they grow and remain competitive, they can often create new opportunities for those displaced workers in other sectors of the business.

Moreover, popular claims of mass unemployment can be dismissed out of hand.[30] Companies invest in process innovations to cut costs. Competition forces them to pass a significant share of those savings to consumers in the form of lower prices (the remainder going to workers in the form of higher wages, and to shareholders in the form of greater returns on investment). This added purchasing power is not buried; it is spent, 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."[31] There is simply no reason to believe this "law of economics" will somehow be repealed, by robots or any other new technology, going forward.

CONCLUSION

The next production revolution will be a welcome development for a global economy that is sputtering and experiencing lagging growth and investment. This new technology wave should lead to a virtuous cycle of increased investment, higher productivity, more spending, and in turn more investment. While it appears likely that developed nations will benefit more from the next wave, virtually all nations should benefit from the increased availability of more powerful, diverse, and lower-cost production technologies. But if developing nations want to maximize these benefits, they will need to avoid innovation-hampering tax and regulatory policies, while at the same time fostering policies to facilitate enterprise adoption of these systems.

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