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The Economics of Artificial Intelligence and Robotics

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Advances in Artificial Intelligence (AI) technology and related fields like robotics have made it possible that automated systems will reach and then exceed human performance on more and more tasks. The affected fields span the economy, from health and education to energy and the environment.

In this article, we define AI and provide some historical context with emphasis on what economists have called "creative destruction." The key issue is whether AI is fundamentally different from previous leaps in automation. Will this finally be the technical advance that makes large numbers of humans redundant?


REUTERS/Jason Lee

A robot server carries dishes to fulfill diners' orders in Haidilao's new artificial intelligence hotpot restaurant in Beijing, China, November 14, 2018.

What is Artificial Intelligence?

Economists Jason Furman and Robert Seamans describe AI as "a range of advanced technologies that exhibit human-like intelligence, including machine learning, autonomous robotics and vehicles, computer vision, language processing, virtual agents and neural networks."[1] Economists at the University of Toronto argue that the essence of AI is prediction.[2] People try to make good predictions every day—anything from deciding whether to take an umbrella on a walk to making stock investment decisions.

AI and all of its applications such as autonomous vehicles, 3D printing, and robotics have to do with prediction, the process of filling in missing information. It takes information we do have (big data) and uses it to generate information we don't have. Examples include machines predicting:

- Whether a credit card transaction is fraudulent.
- Whether a tumor in an image is malignant.
- What you will order next on Amazon.

The law of demand says that when the price of a good or service goes down, we use more of it. Thus, we will start to use prediction more as it becomes more affordable.

Better prediction will be made possible by the availability of big data from sources such as e-commerce, business, and social media. This provides the raw data for AI. The other key ingredient is improvement in machine learning. A now-ordinary "smart thermostat" provides a good illustration. Instead of requiring detailed programming about your habits and temperature preferences, a learning thermostat observes when you set the temperature up and back. It "learns" your temperature preferences without detailed programming by you. Big data comes into play when the smart thermostat, connected to the Internet, automatically reacts to weather reports from your zip code to fine-tune its settings. All of this makes the smart thermostat outperform a manual thermostat

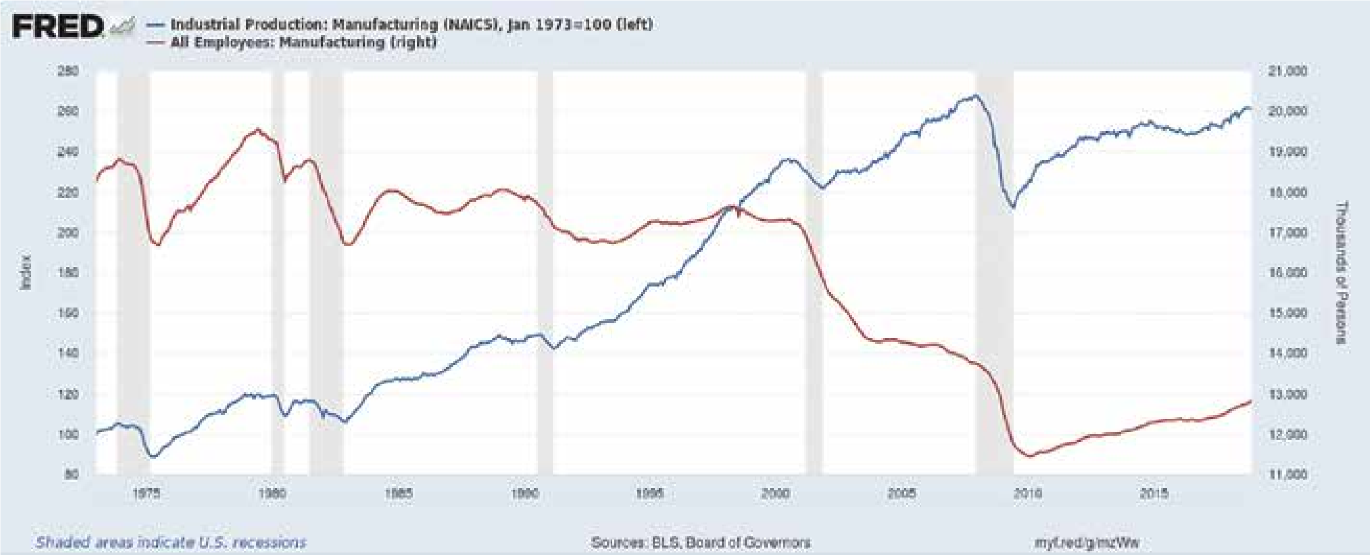

Figure 1: Manufacturing Output and Employment

The blue line shows manufacturing output; the red line shows employment in manufacturing. Starting in the 1980s, manufacturing employment started to fall, while output continued to rise.

Source: U.S. Bureau of Labor Statistics and Board of Governors of the Federal Reserve System, retrieved from FRED®, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/graph/?g=mzWF.

both in comfort and in energy savings. The smart thermostat also provides a miniature example of forces that could affect a broad variety of jobs and enterprises. If a thermostat can learn about your heating and cooling preferences, can a medical AI program learn to diagnose diseases? Can a legal AI program learn to write adoption papers? The key element is not the complexity of the task, but the ability of an AI program to learn rather than just follow pre-programmed settings. And that ability is growing daily with advances in AI.

Historical Context

The term "robot apocalypse" is a modern expression that refers to a fear of technological advance, but automation anxiety is nothing new. For example, in 1589, Queen Elizabeth refused to grant the inventor of a mechanical knitting machine a patent for fear it would put knitters out of work.[3] In the early nineteenth century, English textile artisans called Luddites attempted to prevent the mechanization of the textile industry, fearing that machines would replace labor in the industry. Even John Maynard Keynes worried about widespread technological unemployment "due to our discovery of means of economising the use of labour outrunning the pace at which we can find new uses for labour."[4]

Joseph Schumpeter described the churning in a dynamic economy as "creative destruction." New processes or technologies destroy jobs, firms, and industries even as those changes also give rise to new jobs and industries. The overall effect is an increased standard of living, even as some individuals are left worse off.[5] Schumpeter's creative destruction has been going on at least since the industrial revolution in Britain around 1760. In spite of past fears, the economy consistently produced more jobs than it lost during creative destruction. Many economists see automation and AI as simply the next chapter in this continuing story.

Others worry that this time is different, and the public shares that concern. A 2017 Pew Research survey found 72 percent of respondents expressing worry about a future where robots and computers can do many human jobs.[6] The issue is a common topic in the national news. For example, a recent headline from *Business Insider* suggests that "machines may replace half of human jobs."[7] These concerns are amplified by opinion leaders as diverse as the late physicist Stephen Hawking, who feared that AI might be the worst thing to happen to civilization, and Tesla CEO Elon Musk, who thought AI robots might become lethal. What can economic reasoning add to this discussion?[8]

The Economics of Automation

Economists Daron Acemoglu and Pascual Restrepo have developed a framework for thinking about the future of technological change. In this framework, for any given "job," some tasks might be automated, and others are completed with human labor. Their model identifies four processes at work.[9]

1. The Displacement Effect. The displacement effect describes how capital replaces human labor. As technology becomes less expensive (relative to

REUTERS/Darrin Zammit Lupi

Research support officers and PhD students Luca Bondin and Foaad Haddad discuss an artificial intelligence project to train robots to autonomously carry out various tasks, at the Department of Artificial Intelligence in the Faculty of Information Communication Technology at the University of Malta in Msida, Malta, February 8, 2019.

labor), firms will substitute capital for labor for an increasing number of tasks. This displacement effect helps explain how U.S. manufacturing is near an all-time high, but manufacturing employment has decreased (see Figure 1, on p. 85). On its own, the displacement effect results in a decrease in the demand for labor.

Anxiety about automation has historically emphasized the displacement effect, but there are three countervailing effects at work.

2. The Productivity Effect. Investment in capital increases productivity (output per worker per unit of time). Firms invest in productivity-increasing capital to decrease production cost, thereby increasing the odds of earning a profit. For consumers, this translates into lower prices for the goods and services subject to automated production. These lower prices make households effectively richer, and the result is increased overall demand for goods and services. This increase in overall demand for goods and services also brings increased demand for labor.

History provides a good example of the productivity effect in banking. When ATMs were introduced in the 1970s, many people feared bank tellers' jobs would become obsolete. As it turned out, ATMs decreased the operating costs of bank branches and the banks opened more branches. With additional branches, the banks hired additional tellers. The net result was that overall bank teller employment increased. Over time, ATMs changed the tasks performed by tellers rather than replacing the work of tellers. With the ATM dispensing cash and taking deposits, bank tellers specialized in relationship banking—offering customer services and selling other bank services.[10]

The productivity effect has been powerful in countering the displacement effect, but not big enough to replace the displaced jobs on its own.

3. The Capital Deepening Effect. As technology improves and becomes more affordable, older capital is replaced with newer, more productive capital. This increases the productivity of tasks that had already been replaced by labor, so additional jobs are not displaced. But the higher productivity generates higher real incomes and an increase in the demand for labor, just as with the productivity effect.

Even after considering the contributions of the productivity effect and the capital deepening effect, the displacement effect reduces the share of labor in national income over time. However, there is one additional force that has pushed the production mix to be more labor-intensive.

4. New Tasks. Historically, new tasks, jobs, and industries have emerged during periods of automation. The reduction of agriculture in the labor force, from 41 percent in 1900 to less than 2 percent by 2000, coincided with a large increase in employment in other sectors.[11] The millions of people exiting the agricultural sector would have been hard to employ—but new jobs in factories and supporting professions took up the slack. These new tasks, ranging from engineering and accounting to management, are a vital piece of the puzzle.

Research suggests that about half of the employment growth from 1980 to 2010 resulted from new tasks and job titles.[12] Of course, because these jobs accrue to industries that have not yet been developed, it is difficult to predict where these jobs will emerge. This also helps explain anxiety about automation—it is difficult to predict jobs in industries that do not exist. The worried 1920 farmer could not have predicted the jobs for factory workers producing televisions in the 1950s, the computer programming jobs of the 1990s, or the emergence of mobile phone app developers today.

Of course, displaced farmers don't easily transition to factory production, computer programming, or app development. It is no coincidence that the movement of the United States from agriculture to industry in the twentieth century coincided with the "high school movement." This change, with mandatory enrollment in school until the age of 16, increased enrollment in U.S. high schools from 18 to 71 percent. This daring and dramatic investment in human capital gave the United States the most flexible, skilled, and productive workforce in the world by the end of the twentieth century.[13] Economists suggest that investment in human capital will be important to smooth the transition to even greater automation and artificial intelligence in the future.[14]

Economic Costs of AI

AI will bring winners and losers. Winners will include those whose skills work well with, or "complement," AI. Losers will be those whose skills compete against, or "substitute," for AI. The losers could include some fairly high-skilled individuals. For example, advances in medical imaging hardware and software could allow medical diagnoses to be made more reliably. The point is not that foolproof computer programs could make the diagnoses, but that hardware and software with the ability to learn over time from different cases could approach or exceed the skill of an expensive medical specialist. As another example, tax preparation software has allowed less-skilled tax preparers to replace certified accountants in some situations. In cases such as these, the demand for high-skill computer programmers also increases slightly but their work diffuses widely and can be scaled to any size cheaply. One result of all this change, critics worry, could be greater income inequality.

Another concern is that a few companies will dominate. Amazon, Facebook, and Google are at the top of the list. But we have seen this movie before. AT&T once controlled telecommunications. Microsoft and Intel once held a near monopoly in information technology. Today Google dominates online searches and Facebook dominates social media. But will they hold on against their competitors?

Finally, will a few countries dominate? Currently, the United States leads the world in AI and robot technology. However, some people assume that the country with the most robots will emerge as the next economic superpower. In this scenario, more investment in robots will result in higher gross domestic product, and, on average, richer citizens. On the other hand, countries that resist automation will lose out not just on wealth creation but new jobs as well.

The Information Technology and Innovation Foundation, one of the world's leading science and technology think tanks, argues that the United States is falling behind in adoption of robots. China, on the other hand, is adopting robots so much faster than everyone else that, within a decade, it could lead the world in use of robots.

Solutions and Policies

Many people worry that automation and the coming wave of artificial intelligence will disrupt labor markets and income distribution to the point that government policy intervention will be demanded. In fact, some of the people expressing automation anxiety are those who helped create the tech industry. Bill Gates suggests that government should tax the labor performed by robots to compensate those who lose jobs to automation. Gates suggests that the resulting tax revenues be used to finance jobs taking care of the elderly and working with children in schools. The tax would also slow the trend toward automation.[15] Mark Zuckerberg (Facebook)[16] and Elon Musk (Tesla)[17] have both proposed a government-funded universal basic income (UBI) for all. This would be a tax-funded and unconditional income paid to all citizens regardless of employment status or income level. Thus, the new "winners" of the economy would be taxed in an attempt to distribute the benefits of automation more evenly and provide a basic, sustainable income for households negatively affected by automation.

Economists fear the unintended consequences of UBI. The issue is not that automation will render the vast majority of the population unemployable. Instead, it is that workers will either lack the skills or the ability to successfully match with the good, high paying jobs created by automation and AI-related technology.

Implications for Students, Teachers, and Schools

Whether or not dramatic changes for the labor market are on the horizon, there are strategies that students and schools can pursue now. Automation easily substitutes for any task that can be reduced to computer code, such as routine and repetitive tasks. Automation cannot easily substitute for tasks that require a human touch, such as caregiving, or creative thinking. Future growth lies in the skills needed as new tasks and industries emerge. Andrew McAfee, co-director of the MIT Initiative on the Digital Economy, suggests that students pursue a double major: one in liberal arts to develop problem-solving, creativity, and critical-thinking skills and another in a STEM area (science, technology, engineering, and mathematics) to develop quantitative and technological skills.[18] This pairing reflects what many economists suggest about the jobs of the future, where human skills and judgment will be bundled with technological skills. Workers must acquire the skills necessary to ensure that technology is a complement rather than a substitute for their human capital. And, in the future, it will be more likely that education will not end with a high school or postsecondary education; employability will likely mean constantly upgrading skills and education as the technology changes.

Notes

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