COLLECTED ESSAYS

Technology, Automation and Employment

Will this Time be Different?

Steven Globerman, Contributing Editor

FRASER INSTITUTE

2019

Contents

Executive Summary

Western societies have exhibited a continuing worry that automation, particularly automation associated with artificial intelligence, will lead to massive unemployment and the impoverishment of large segments of society. In different epochs, technological change has triggered concerns and social protests. Those concerns date back to the early stages of the industrial revolution and the use of coal-fired weaving machines to automate textile manufacturing, and they continue through to the present-day and adoption of computerized algorithms that "learn" how to automate tasks through the use of data-driven "machine learning."

In fact, the history of automation affirms that concerns about technological change causing widespread unemployment are misguided. Indeed, as Art Carden and Livio DiMatteo discuss in their contributions to this volume, technological change, on balance, increases the overall demand for labour, while contributing to higher living standards for most segments of society. To be sure, automation has led to many specific tasks being done more efficiently by machine than by human labour. At the same time, increased efficiency associated with automation increases society's real income thereby enabling people to increase their consumption of new and improved goods and services. Higher real income generates an increased demand for workers needed to produce the increased quantity and variety of products that are purchased by wealthier consumers.

Productivity increases associated with automation therefore contribute to increased employment by improving real standards of living which, in turn, stimulates demand for all sorts of goods and services, the production of which requires workers. Workers are also needed to implement automation. An obvious example is the explosion in the demand for computer programmers and software engineers to implement the use of computers in a wide range of business and human activity. The essay by Art Carden puts into historical context the phenomenon of how new occupations emerge from automation even as older occupations become less prominent.

Recently, prominent entrepreneurs such as Elon Musk, the founder of Tesla, and Mark Zuckerberg, the founder of Facebook, have raised the prospect that a new wave of automation associated with Artificial Intel-

ligence (AI) will lead to a departure from historical experience. Specifically, they anticipate that the incorporation of human-like intelligence into computer algorithms will finally result in mass unemployment as automated robots and the like can do anything that a human being can do only more efficiently. While this argument cannot be dismissed out of hand, it is more likely that history will repeat itself. Specifically, productivity gains from the use of AI will improve real income levels and, as in the past, the resulting expansion of the economy will increase the demand for workers, even as AI substitutes for some labour market skills.

In his essay in this volume, Steven Globerman discusses several studies that have attempted to estimate how AI will affect the demand for labour. The studies break different occupations into the underlying tasks associated with the occupations and then ask the question: how easily can AI-automation carry out the specific tasks identified? The studies tend to conclude that AI-automation can directly substitute for a relatively small set of tasks. At the same time, it increases the demand for other tasks that are likely better done by humans. For example, AI is enabling physicians to more accurately diagnose human diseases at earlier stages. This development is expected to reduce the demand for skills related to reading and interpreting medical scans produced by MRI and CT machines or for interpreting blood tests. However, at the same time, it should increase the demand for skills related to managing and treating human diseases. As another example, AI algorithms are increasingly being used by financial management companies to automate the life-cycle investment decisions of savers. This development presumably reduces the demand for human investment management skills, other things constant. However, investors need to be educated about the net benefits of automated wealth management funds, which automatically adjust the mix of assets held in individual portfolios to the age and risk preferences of individual investors. This, in turn, generates an increased demand for education-related tasks within wealth management firms, as well as increased demand for analytical skills that can "fine-tune" algorithms to reflect new information about the anticipated risks and returns of different types of assets.

As Carden and DiMatteo emphasize, automation changes the mix of skills demanded in an economy. This implies that the skill mix of the labour force is constantly in need of change to accommodate the change in the demand for specific skills. Historically, the speed of automation has been relatively slow, a point discussed in Globerman's essay. The relatively slow rate of technological diffusion provides time for workers, particularly each new generations of workers, to invest in human capital that is complementary to each specific vintage of automation. In this regard, AI is unlikely to be an exception to historical experience. The various barriers to the rapid spread of new technologies that Globerman discusses are likely to confront the adoption of AI as they did other vintages of automation.

In fact, if the AI experience is going to be different from historical experience, it might be because of significant reductions in the supply of labour associated with aging populations and historically low birth rates. DiMatteo discusses this possibility in detail and pays particular attention to Canada's future labour supply prospects. He documents the forecast declines in both Canada's labour force growth rate and the labour force participation rate. He notes that concerns about AI leading to widespread unemployment might be "doubly inappropriate." Specifically, if AI leads to an overall increase in the demand for labour at the same time as the labour supply growth rate is decreasing, the outcome will be exactly the opposite of what is projected by doomsayers. Namely, there will be reduced unemployment and higher real wages earned by those gainfully employed. AI-related automation will follow a direction consistent with earlier epochs of automation except that a shrinking labour force growth rate will accentuate the translation of productivity gains into higher incomes for workers.

1. A Curse on (Intelligent) Machines?

Art Carden

Introduction[1]

A spectre haunts Europe and the United States, and for that matter, the entire world: the spectre of widespread, systematic, irreversible technological unemployment. As spectres go, it isn't particularly new or original, however. It has been hanging around for centuries without ever really doing anything for long periods. Fear? Yes. Reality? Not so much.

It has lurked around mostly in commentary, analysis, and fear. David Ricardo was an optimist in the early nineteenth century before beginning to worry about technological unemployment (Mokyr et al., 2015: 33). John Maynard Keynes worried about it in the early twentieth (Mokyr et al., 2015: 31-32). With the diffusion of artificial intelligence, machine learning, and smart devices, many people are worrying about it anew in the early twenty-first century. What the economist Joseph Schumpeter called "gales of creative destruction" have blown regularly and strongly since the middle of the 1700s without destroying employment opportunities *en masse*. In the long run, the "creative" gales have been more powerful than the "destruction" gales and created new opportunities to replace old ones.

Any change to the status quo will make at least some people better off while making at least some people worse off. Market-driven, technology-enhanced creative destruction has been the greatest positive-sum force in history, and while some people are indeed made worse off—even in the long run—by technological change, the idea that changing technology will create mass unemployment has been tried, measured, and found wanting.

---

[1] This essay is drawn from a larger, ongoing project with Deirdre McCloskey. See Carden and McCloskey (2018) and McCloskey (2006, 2010, and 2016) for more. See also Gordon (2018) and Mokyr (2018) for a recent discussion of technology, productivity growth, and the future of employment. I am thankful to an anonymous referee for valuable comments and suggestions.

Artificial intelligence, we are told, is different. Previous gales creatively destroyed merely mechanical human actions. They were substitutes for muscle and for, at best, low-level cognitive functions like calculation. Artificial intelligence, on the other hand, threatens to replace higher-order functions. What will people do once intelligent machines can solve problems that are now the exclusive domain of our thinking and problem-solving brains?

The *specific* answer, unfortunately, is "we don't know." Yogi Berra was right: it's very hard to make predictions, especially about the future. While we cannot predict precisely how people will react to their new economic and technological reality, the broad sweep of history gives us some ideas as to the dim outlines of what we should probably expect. Some changes might be warranted, like a Basic Income Guarantee or a system of public dividends from government-owned mutual funds such as that advanced by Andrews (2017). Widespread, morbid pessimism about the future of employment, however, is not—as long as we keep our ethical and institutional wits about us and refrain from throttling labour markets with ever-more regulation and taxation.[2]

In his 1849 essay *What is Seen, and What is Not Seen*, the economist Frederic Bastiat considered economic, political, social, and cultural worries about machinery and its alleged impoverishing effects. He concluded: "to curse machines is to curse the human mind!" This, I think, is true, whether those machines are "dumb" (as they were in 1849 or 1949) or "smart" (as they are in 2019).

Bastiat points out the absurdity in the notion that technological progress is the enemy of prosperity. It implies, he points out,

> that activity, well-being, wealth, and happiness are possible only for stupid nations, mentally static, to whom God has not given the disastrous gift of thinking, observing, contriving, inventing, obtaining the greatest results with the least trouble. On the contrary, rags, miserable huts, poverty, and stagnation are the inevitable portion of every nation that looks for and finds in iron, fire, wind, electricity, magnetism, the laws of chemistry and mechanics—in a word, in the forces of Nature—an addition to its own resources and it is indeed appropriate to say with Rousseau: "Every man who thinks is a depraved animal." (Bastiat, 1849)

[2] See Carden and McCloskey (2018) on ethical consensus and economic progress. Carpenter et al. (2017) summarizes occupational licensing and regulation in the United States.

Bastiat concludes, though, that the effect of machines is "not to make jobs scarce, but to *free* men's labour for other jobs."

The historical record and recent research into the economics of machine learning, technology adoption, and the relationship between the diffusion of robotics and employment supports an optimistic case for the future of technology and employment. As technology continues to progress, the lines separating "labor" and "leisure" will get fuzzier. It won't likely give us good reason to fear that artificial intelligence will reduce people to jobless penury. While new technologies foreclose some opportunities, they create new ones. That has been the case for the last couple of centuries. It is not likely to change substantially.

The past

For centuries, major economic shifts have happened without destroying opportunities to work. The development of settled agriculture reduced hunting and gathering as a share of overall economic activity.[3] The Industrial Revolution was accompanied by rising agricultural productivity and a transition of labour out of agriculture and into other sectors. Almost everyone used to work on farms. Now, hardly anyone does. The fraction of the labour force in farming fell precipitously in the nineteenth century and almost disappeared in the twentieth, falling from 41 percent of workers in 1900 to 2 percent in 2000 (Autor, 2015: 5).

Industries and jobs come and go.[4] The "wave of gadgets [that] swept over England" during the Industrial Revolution included many labor-saving devices.[5] The same is true of the wave of gadgets sweeping over the 21st century world. They have economized on physical and cognitive labor, but they have not replaced all the jobs. Not everyone is strictly better off because of structural changes to the economy—Allen (2018) discusses how hand-loom weavers suffered because of the emergence of the power loom, for example—but overall, market-driven creative destruction has been history's greatest positive-sum game.

In 1910, about 5 percent of US workers worked on railroads (McCloskey, 2017). In 2016, it was about 0.07 percent—a fraction smaller by a factor of almost 100.[6] At one point, AT&T employed some 350,000

---

3 See Munger (2018) for a discussion of what made these revolutions "revolutionary."

4 The next two paragraphs rely on and draw from McCloskey (2017) and Autor (2015: 5-6).

5 The phrase is from Ashton (1971 [1948]: 42) as quoted in Temin (1997).

6 Author's calculations from Bureau of Labor Statistics (2019a and 2019b).

manual telephone operators—more than three times as many people as currently work as railroad workers, according to the US Bureau of Labor Statistics—to do what is today completely automated. With the advent and diffusion of the automobile, equestrian jobs like stable hands and blacksmiths largely disappeared. The number of bank tellers in the United States increased from 500,000 to 550,000 between 1980 and 2010 in spite of the widespread diffusion of automated teller machines (Autor, 2015: 5-6). Automatic elevators displaced elevator operators, and yet the elevator operators did not starve.

This suggests that the intuitions of some of the more optimistic eighteenth and nineteenth century interpreters were, largely, accurate.[7] Sir James Steuart thought technology-induced dislocation would be temporary. John Stuart Mill was of the view that technological change did not hurt "the laboring classes in the aggregate." Even Karl Marx, though he thought the capitalist mode of production itself led to immiseration, believed that in the long run, technological change would enrich people. Beginning in the middle of the eighteenth century, accelerated technological progress brought about by a business-loving civilization led to a larger, better-fed, longer-lived, better-provisioned population that still has plenty of work to do.

Mokyr et al. (2015) note that there is an important difference between creative destruction leading to displacement in some sectors and creative destruction leading to widespread unemployment. By focusing on the easy-to-see victims of technological displacement, we risk failing to see technology's widespread benefits for almost everyone else. The development of the power loom, for example, meant "poverty accompanied progress" as it rendered obsolete the skills of hand-loom weavers (Allen 2018: 381). However,

> [i]n the end, the fears of the Luddites that machinery would impoverish workers were not realized, and the main reason is well understood. The mechanization of the early 19th century could only replace a limited number of human activities. At the same time, technological change increased the demand for other types of labor that were complementary to the capital goods embodied in the new technologies. This increased demand for labor included such obvious jobs as mechanics to fix the new machines, but it extended to jobs for supervisors to oversee the new factory system and accountants to manage enterprises operating on an unprecedented scale. More

7 This paragraph relies on Mokyr et al. (2015: 33ff)

> importantly, technological progress also took the form of *product* innovation, and thus created entirely new sectors for the economy, a development that was essentially missed in the discussions of economists at the time. The children of the displaced handloom weavers not only had the option to work in machine-intensive cotton mills; they could also become trained engineers and telegraph operators. Nineteenth-century political economists lacked an ability to predict new job categories like the personal fashion consultants, cybersecurity experts, and online-reputation managers of the twenty-first century. (Mokyr et al., 2015: 36)

Technological progress has eliminated or at least revolutionized virtually every job people did in 1800 and 1900, and yet the result has been mass prosperity and rising standards of living rather than starvation. A curse upon machines, indeed.

The present

"But this time is different, isn't it?" It's reasonable to suspect that someone looking backward and confidently predicting an abundant future is akin to the man falling from a 100-story building and saying "everything has worked out so far" as he passes the fiftieth floor. Even then, the mere fact that this time *might be* different doesn't mean that this time *actually is* different—or that our difficulty imagining what people will do as artificial intelligence takes over more and more tasks is particular cause for concern. Dips in labour force participation notwithstanding, it's not clear that technology-driven structural unemployment and under-employment is right around the corner. The fault lies not in technological change, but in rules and regulations that make the labour market less flexible.

The relationship between industrial robots, employment, and labour productivity provides important guidance. Graetz and Michael (2018) argue that as firms adopted industrial robots, labour productivity rose. They note that there might have been some reductions in low-skill employment but no reduction in employment overall. There is at least some preliminary evidence of lower wages and employment in sectors where robots compete directly (Acemoglu and Restrepo, 2017), but far from a consensus that large-scale technological change represents a threat to overall employment.

Any change, not just a technological change, disrupts the status quo and likely leaves at least someone worse off. Increasing trade with China as a result of their accession to the World Trade Organization, for example, reduced earnings and opportunities for workers with easy-to-replace skills and for whom overseas competitors are net substitutes for the skills they possess (Autor et al., 2016). China joining the World Trade Organization, however, was a one-time event that changed the pattern of specialization and exchange and not necessarily overall trends in wages and productivity.[8]

Short-run disruption has been true of many labour-saving technologies, and it will likely continue to be true for technologies that economize on cognitive tasks. It will, however, continue to reward skills that are complements to rather than substitutes for what computers can do. Technological changes that make things like machine learning possible via the deployment of artificial intelligence work to make high-skill labour more productive and thereby increase the returns to these skills. Contextualization is one example. While it likely isn't impossible, skills like compassion and empathy are difficult to digitize and replicate. Hence, empathetic curation becomes a valuable skill. This sends an important signal into markets for labour and schooling. Those who wish to prosper should invest in skills that are complements to technology.

The future

What the "right skills" are, however, is not quite anybody's guess but also not easy for even the best and brightest minds to foresee. David Ricardo embraced technological pessimism and was badly mistaken. Nonetheless, projections from the US Bureau of Labor Statistics help us see through a glass darkly to at least some of the fields where opportunities might emerge.

Artificial intelligence has been replacing cognitive tasks without replacing the need for human work. A pocket calculator is a type of artificial intelligence. Basically, hard drives and cloud storage are external brains analogous to the printed page of a few centuries ago but many times more effective and with almost infinitely greater capacity as a means of storing knowledge and information. The search tools we use to access documents and ideas scattered across these storage media require types of artificial intelligence, too—and that creates opportunities for tech support and information technology consultants.

Changing technology shrinks some sectors but expands others, and over time the labour from shrinking sectors can move into expanding sectors. Table 1 reports median hourly pay, typical entry-level education, number of jobs in 2016, and the projected employment change from 2016 to 2026 for "Computer and Information Technology Occupations" in the

[8] I am grateful to an anonymous referee for pointing this out.

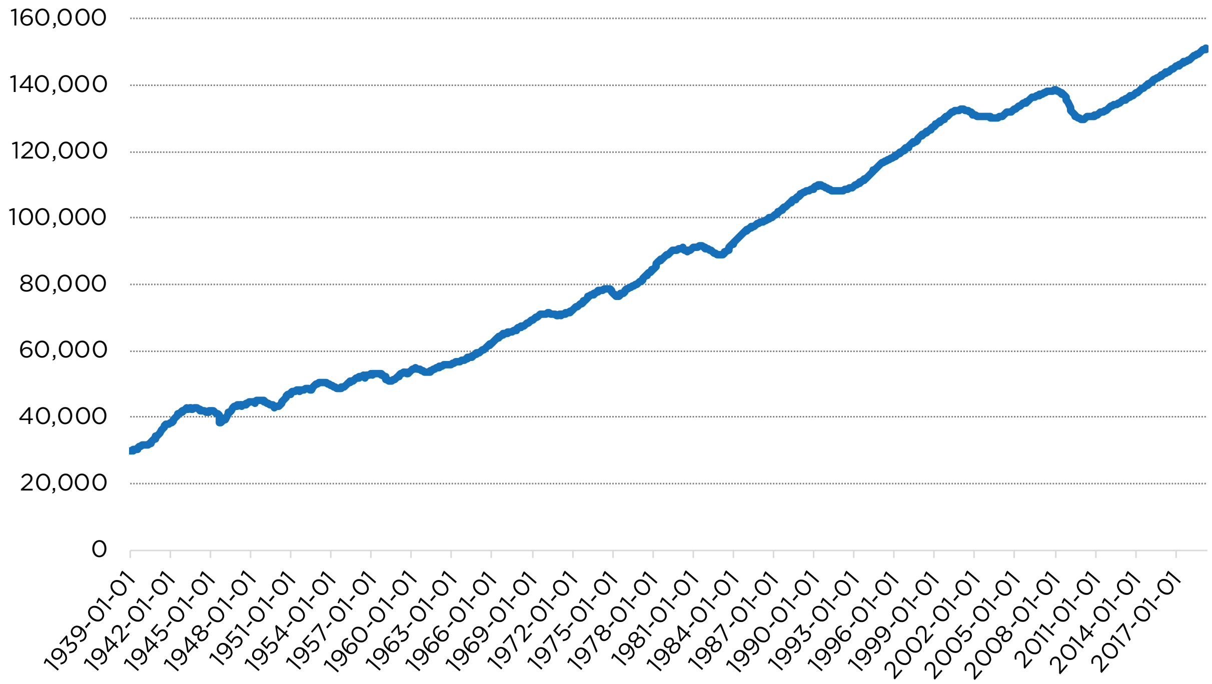
Table 1: Computer and Information Technology Occupations: Earnings, Jobs, and Projected Growth

Job	2017 Median Hourly Pay	Typical Entry-Level Education	Number of Jobs, 2016	Projected Employment Change, 2016-2026
Computer & Information Research Scientists	$55.06	Master's Degree	27,900	5,400
Computer Network Architects	$50.31	Bachelor's Degree	162,700	10,500
Computer Programmers	$39.54	Bachelor's Degree	294,900	-21,300
Computer Support Specialist	$25.39	Variable	835,300	88,500
Computer Systems Analysts	$42.44	Bachelor's Degree	600,500	54,400
Database Administrators	$41.84	Bachelor's Degree	119,500	13,700
Information Security Analysts	$45.92	Bachelor's Degree	100,00	28,500
Network and Computer System Administrators	$38.99	Bachelor's Degree	391,300	24,000
Software Developer	$49.79	Bachelor's Degree	1,256,200	302,500
Web Developers	$32.69	Associate's Degree	162,900	24,400

Source: Bureau of Labor Statistics (2019c)

BLS *Occupational Outlook Handbook* (Bureau of Labor Statistics, 2019c). It is suggestive, not conclusive, but these data illustrate how creative destruction works. As some occupations disappear and some industries shrink, new opportunities emerge. A word of caution is in order: this represents a small selection of the labor market, but most of the occupations in computers and information technology are growing as fast as or faster than average. Relatively high earnings and job growth in this case suggest that it would be prudent to develop skills that are complementary to ever-improving information technology.

Figure 1: All Employees: Total Nonfarm Payrolls, 1939-2019



Source: Bureau of Labor Statistics (2019d).

Brynjolfsson et al. (2018:44) explain how and why machine learning likely will not destroy all the jobs. A "job" is in fact a collection of tasks, and they note that while the task content of certain jobs will change based on what can be delegated to machine learning, "few if any occupations have all tasks that are [suitable for machine learning]." Benzell and Brynjolfsson (2019) emphasize the importance of "genius," an input that cannot be digitized.

There are elements of the human that serve as examples of "genius" that cannot be digitized easily. There will still likely be a demand for explicitly *human* services due, in part, to a demand for what Adam Smith (1790) called the "mutual sympathy of sentiments." As Pratt (2015: 58) points out, "No one proudly wears T-shirts declaring when they listened to a recorded song." It is this fact that makes it unlikely that people will no longer see any need for one another's services. In any event, total nonfarm payroll employment in the United States continues its steady upward march with only brief pauses due to business cycles. Economists criticize what they call the "lump of labour" fallacy, noting that it is a *fallacy* because it assumes there is a fixed amount of work to be done. Its fallaciousness is evident in a graph of total nonfarm payrolls in the United States since 1939. Technology has changed, mightily, and population has grown by a factor of less than three. Yet nonfarm payrolls have grown by a factor of about five (figure 1). With the move off the farms, non-farm sectors expanded rapidly enough to find work for those who would have otherwise been agriculturally employed. Intelligent mechanization might draw labour out of sectors that can be automated and reduce the share of income going to labour in those sectors. That so much artificial intelligence is on so many margins a complement to rather than a substitute for human labour makes it unlikely that mass technological unemployment is on the horizon.

Conclusion

As Mokyr et al. put it, "If someone as brilliant as David Ricardo could be so terribly wrong in how machinery would reduce the overall demand for labor, modern economists should be cautious in making pronouncements about the end of work" (2015: 45). At various times, people have thought that machinery would mean no jobs left for anyone. Yet employment opportunities have continued to grow.

By 2015, someone who wanted the standard of living of someone in 1915 would have been able to get it with a mere 17 weeks of work per year (Autor, 2015: 8). Not surprisingly, we choose to use some of our greater productivity to enjoy more leisure—leisure which is filled with all sorts of technological wonders and which scarcely resembles "'leisure' in the preindustrial past that involved a fair amount of sitting in the dark" (Mokyr et al., 2015: 44). In 1999, Robert W. Fogel wrote of American super-saturation with material goods like radios (Fogel, 1999). Twenty years later, we have not run out of consumption possibilities but, rather, have super-saturated our lives with interactive screens. In fact, dealing with technological overload has become its own growth industry. One can buy software that will block off the dark (or just fun) corners of the internet, a frequent conversation among parents is how to manage "screen time," and people are making their livings blogging, speaking, and consulting about managing the cornucopia. With ever-decreasing amounts of effort, one can live a life unlike anything our ancestors could have imagined.

As artificial intelligence takes over more and as the world integrates further, the US and Europe might lose industrial and technological "leadership." But so what if the future is Chinese? Or African? There is no economic play-off in which a country gets a higher seed for getting to Mars first or inventing the best smartphone. Creative destruction is a game we can all play and which creates a better future for our children in the long run.

References

Acemoglu, Daron, and Pascual Restrepo (2017). *Robots and Jobs: Evidence from U.S. Labor Markets*. NBER Working Paper 23285. National Bureau of Economic Research. <https://www.nber.org/papers/w23285.pdf>, as of June 4, 2019.

Agrawal, Ajay, Joshua S. Gans, and Avi Goldfarb (2018). Human Judgment and AI Pricing. *AEA Papers and Proceedings* 108: 58–63.

Allen, Robert C. (2018). The Hand-loom Weaver and the Power Loom: A Schumpeterian Perspective. *European Review of Economic History* 22: 381–402.

Andrews, Marcellus (2017). *The Vision of a Real Free Market Society: Re-Imagining American Freedom*. Routledge.

Ashton, T.S. (1971 [1948]). *The Industrial Revolution*. Oxford University Press.

Autor, David H. (2015). Why Are There Still So Many Jobs? The History and Future of Workplace Automation. *Journal of Economic Perspectives* 29, 3: 3–30.

Autor, David H., David Dorn, and Gordon H. Hanson (2016). The China Shock: Learning from Labor-Market Adjustment to Large Changes in Trade. *Annual Review of Economics* 8, 1: 205–240.

Bastiat, Frederic (1849). *What is Seen and What is Not Seen*. Seymour Cain (trans.), George B. de Huszar (ed.). The Foundation for Economic Education, Inc. <https://www.econlib.org/library/Bastiat/basEss.html?chapter_num=4#book-reader>, as of March 1, 2019.

Benzell, Seth G., and Erik Brynjolffson (2019). *Digital Abundance and Scarce Genius: Implications for Wages, Interest Rates, and Growth.* NBER Working Paper 25585. National Bureau of Economic Research.

Berg, Maxine (1980). *The Machinery Question and the Making of Political Economy, 1815–1848*. Cambridge University Press.

Bessen, James (2015). Toil and Technology. *Finance and Development* 52, 1: 16–19.

Broadberry, S., M.S. Campbell, Alexander Klein, Mark Overton, and Bas van Leeuwen (2015). *British Economic Growth, 1270–1870*. Cambridge University Press.

Brynjolfsson, Erik, Tom Mitchell, and Daniel Rock (2018). What Can Machines Learn and What Does It Mean for Occupations and the Economy? *AEA Papers and Proceedings* 108: 43–47.

Buchanan, James M. (1992). *Better Than Plowing and Other Personal Essays*. University of Chicago Press.

Bureau of Labor Statistics (2019a). "Railroad Workers." *Occupational Outlook Handbook*. Government of the United States, Department of Labor. <https://www.bls.gov/ooh/transportation-and-material-moving/railroad-occupations.htm>, as of March 2, 2019.

Bureau of Labor Statistics (2019b). "Labour Force Statistics from the Current Population Survey." *Databases, Tables, and Calculators by Subject*. Government of the United States, Department of Labor. <https://data.bls.gov/timeseries/LNS11000000>, as of March 2, 2019.

Bureau of Labor Statistics (2019c). "Computer and Information Technology Occupations." *Occupational Outlook Handbook*. Government of the United States, Department of Labor. <https://www.bls.gov/ooh/computer-and-information-technology/home.htm>, as of March 8, 2019.

Bureau of Labor Statistics (2019d). *All Employees: Total Nonfarm Payrolls (PAYEMS).* FRED, Federal Reserve Bank of St. Louis. <https://fred.stlouisfed.org/series/PAYEMS>, as of March 8, 2019.

Carden, Art, and Deirdre Nansen McCloskey (2018). The Bourgeois Deal: Leave Me Alone and I'll Make You Rich. In Steven Globerman and Jason Clemens (eds.). *Demographics and Entrepreneurship: Mitigating the Effects of an Aging Population*. (The Fraser Institute): 429–466.

Carpenter, Dick M. II, Lisa Knepper, Kyle Sweetland, and Jennifer McDonald (2017). *License to Work: A National Study of Burdens from Occupational Licensing*. Institute for Justice.

Felten, Edward W., Manav Raj, and Robert Seamans (2018). A Method to Link Advances in Artificial Intelligence to Occupational Abilities. *AEA Papers and Proceedings* 108: 54–57.

Fogel, Robert W. (1999). Catching up with the Economy. *American Economic Review* 89, 1: 1–21.

Gordon, Robert (2018). Declining American Economic Growth Despite Ongoing Innovation. *Explorations in Economic History* 69: 1–12.

Graetz, Georg, and Guy Michaels (2018). Robots at Work. *Review of Economics and Statistics* 100, 5: 753–768.

McCloskey, Deirdre N. (2006). *The Bourgeois Virtues: Ethics for an Age of Commerce*. University of Chicago Press.

McCloskey, Deirdre N. (2010). *Bourgeois Dignity: Why Economics Can't Explain the Modern World*. University of Chicago Press.

McCloskey, Deirdre N. (2016). *Bourgeois Equality: How Ideas, Not Capital or Institutions, Enriched the World*. University of Chicago Press.

McCloskey, Deirdre N. (2017). The Myth of Technological Unemployment. *Reason* (September). <https://reason.com/archives/2017/07/11/the-myth-of-technological-unem>, as of March 1, 2019.

Mokyr, Joel (2018). The Past and the Future of Innovation. Some Lessons from Economic History. *Explorations in Economic History* 69: 13–26. <https://cpb-us-e1.wpmucdn.com/sites.northwestern.edu/dist/3/1222/files/2018/02/PastandFuture-wqsumb.pdf>, as of June 5, 2019.

Mokyr, Joel, Chris Vickers, and Nicolas L. Ziebarth (2015). The History of Technological Anxiety and the Future of Economic Growth: Is This Time Different? *Journal of Economic Perspectives* 29, 3: 31–50.

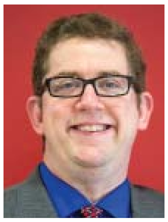
Munger, Michael (2018). *Tomorrow 3.0: Transaction Costs and the Sharing Economy*. Cambridge University Press.

Pratt, Gill A. (2015). Is a Cambrian Explosion Coming for Robotics? *Journal of Economic Perspectives* 29, 3: 51–60.

Smith, Adam (1790). *The Theory of Moral Sentiments*, 6th Edition. A. Millar.

Temin, Peter (1997). Two Views of the British Industrial Revolution. *Journal of Economic History* 57, 1: 63–82.

About the author



Art Carden

Art Carden is Associate Professor of Economics at Samford University in Birmingham, Alabama. In addition, he is a Research Fellow with the Independent Institute, a Senior Fellow with the Beacon Center of Tennessee, a Senior Research Fellow with the Institute for Faith, Work and Economics, and an Adjunct Program Officer in Economics with the Institute for Humane Studies. He teaches regularly at seminars sponsored by organizations like the Institute for Humane Studies and the Intercollegiate Studies Institute. His main areas of research are southern economic history, the history and philosophy of economic ideas, and the effects of "big box" retailers like Walmart and Costco. Art's research has appeared in the *Journal of Urban Economics*, the *Southern Economic Journal, Public Choice, Contemporary Economic Policy*, and *Applied Economics*, among others. His commentaries have appeared in many prominent newspapers and journals, including Forbes.com.

2. Artificial Intelligence and Employment: Will History Repeat?

Steven Globerman

> "Every aspect of our lives will be transformed by (AI). It could be the biggest event in the history of civilization"
> —Stephen Hawking (SAS, undated)

> "Few concepts are as poorly understood as artificial intelligence"
> —Darrell West (2018)

Introduction

As the introductory quotes suggest, few topics are generating as much attention and hyperbole as the impact that artificial intelligence (AI) will have on society, especially on work and business practices. In particular, many prominent business executives and management consultants have argued that widespread applications of AI will dramatically reduce employment opportunities for future generations. For example, Knoess, Harbour, and Scemama (2016) estimate that robotization, digitization, digital self-services, distributed digital advice and sales, and robo-advisors, all applications that will be driven by AI, could result in a 60 to 70 percent reduction in the workforce of service providers from financial services to telecommunications. They note that while these changes will not happen overnight, the pace of change might be faster than many expect. Even more dramatic is Elon Musk's claim that artificial intelligence will cause massive job disruption and that robots will be able to do everything better than humans (Clifford, 2017a). The controversial CEO of Tesla further argues that it's a virtual inevitability that, as robots replace more and more jobs, the United States will have to implement a program of cash payments to everyone (Clifford, 2017b). One can assume that Musk's argument for cash payments, or guaranteed incomes, applies to other countries as well.

To be sure, many others disagree with the view that the widespread adoption of AI will lead to massive unemployment that, in turn, will necessitate major new taxpayer-funded income support programs. Roe (2018) references a number of senior executives in corporate strategy and technology management positions who argue that AI primarily changes the nature of work rather than causing widespread unemployment. Furthermore, while some jobs will certainly be lost as AI takes on skills formerly attributed to humans, new jobs will emerge. Warren Buffet, the CEO of Berkshire Hathaway and an immensely successful investor, cautions that the trend towards automation replacing low-skilled labour is not new. He notes that in 1800, 80 percent of people were employed on farms. Two hundred years later, it was 2 to 3 percent. Productivity improvements meant that fewer people were needed to work on farms, and therefore were free to pursue other vocations (Clifford, 2017b).

The research of economic historians largely supports the claims that in the past, automation has primarily led to changes in the mix of occupations rather than to mass unemployment; it has also led to increases in real income levels rather than an expansion of poverty.[1] Nevertheless, a number of prominent technology experts argue that the AI experience will be different from the historical experience with automation. For example, Parada (2017) contends that it is catastrophically wrong to draw an analogy between AI and previous waves of automation. Specifically, he argues that automation in the past was primarily about mechanical power replacing human muscle. The AI revolution will be nothing like that. When robots become as smart and capable as human beings, there will be nothing left for people to do because machines will be both stronger and smarter than humans. Parada (2017) makes what seems to be the extreme claim that intelligent robots will be cheaper, faster, and more reliable than humans, and that no capitalist in her right mind will continue to employ humans. He goes on to assert that unless society figures out how to distribute the fruits of robot labour fairly, it will be an era of mass joblessness and mass poverty. Frey (2019) offers a more modest but still startling estimate that 47 percent of US jobs could be automated due to AI.

Others have made a similar, if less extreme, argument that AI represents a "different" technological innovation, and that the labour market experiences associated with other major epochs of technological change may not apply in the case of AI. Microsoft founder Bill Gates does not believe that AI will prove to be a bad thing for society. However, he is in the

1 Elsewhere in this volume Art Carden summarizes some of this research.

camp that believes that job displacement will be sufficiently widespread that government will need to direct financial assistance to the many workers who will be hurt by AI adoption with some of that assistance directed at re-education and income support programs (Clifford, 2017b).

The purpose of this essay is to assess the argument that AI's effects on employment will be significantly different from previous episodes of automation. Specifically, we review some expert opinion on how producers are likely to use AI, as well as the limited available evidence on how AI has affected employment up until now. We also consider whether there are reasons to believe that AI will be adopted at a much faster rate than other major innovations so that retraining workers for occupations that are complementary to AI is impractical. Our broad conclusion is that future employment effects and adoption rates of AI are unlikely to be much different from the broad historical experiences of other General Purpose Technologies (GPTs).

This essay proceeds as follows. The next section provides a non-technical overview of what AI is and how it might evolve as a general purpose technology.[2] The following section discusses and assesses different perspectives on how AI interacts with work practices, including whether it is more likely to be a complement than a substitute for human labour in the future. The final section offers concluding comments.

Overview of AI

Professor John McCarthy, the so-called father of AI, defines AI as the science and engineering of making intelligent machines, especially intelligent computer programs (McCarthy, undated). AI is a wide-ranging branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence. AI generally falls under two broad categories: 1) Narrow AI, which is focused on performing a single task extremely well; 2) Artificial General Intelligence, which equips machines with general intelligence that can be applied to solve a wide range of problems. Narrow AI is predominantly the most successful realization, to date, of the technology. However, the creation of machines with human-level intelligence that can be applied to any task is the Holy Grail for many AI researchers, and it is arguably the AI development that underlies most strongly the concerns expressed about AI leading to widespread unemployment.

[2] Brynjolfsson, Mitchell, and Rock (2018) characterize a general purpose technology as being pervasive, improving over time, and generating complementary innovations. For an early discussion of GPT, see Bresnahan and Trajtenberg (1992).

AI is often undertaken in conjunction with machine learning and data analytics. The resulting combination enables intelligent decision-making. AI computer algorithms are designed to make decisions, often using real-time data. Machines equipped with AI algorithms gather information from a variety of different sources such as cameras, sensors, or electronic databases, analyze the information, and act on the insights derived from the information (West, 2018). Machine learning is a branch of AI based on the idea that computerized machines can learn from data by looking for underlying trends or patterns and then making decisions with minimal human intervention.[3] So-called deep learning is a type of machine learning whereby computers are programmed to perform human-like tasks, such as recognizing speech, identifying images, or making predictions. Instead of organizing data to run through predefined equations, deep learning involves setting up basic parameters about the data and "training" the computer to learn on its own by recognizing patterns in the data (SAS, undated).

AI is different from robotic automation. Instead of automating manual tasks, AI performs frequent, high-volume, computerized tasks. Human inquiry is still essential for this type of automation in order to set up and program the "learning algorithm" that addresses the correct question(s) to be answered, such as what a particular individual's credit risk is.[4] AI finds structure and regularities in data, so the algorithm acquires a skill. Robust learning requires a substantial amount of data if structure and regularities in the data are to be reliably identified. As noted earlier, to date, AI has primarily focused on performing single tasks well. For example, an AI system that detects health care fraud cannot accurately detect tax fraud. Presumably, if there are systematic similarities between different types of fraud, they can ultimately be identified through deep learning and a more robust algorithm will emerge that can detect multiple types of fraud.

The ultimate achievement of AI is to create computer programs that can solve problems as well as humans can. There are prominent barriers standing in the way of this development. As Parada (2017) notes, computers can now be built with roughly the raw processing power of the human

---

3 Brynjolfsson, Mitchell and Rock (2018) define machine learning as a sub-field of AI that studies the question: How can we build computer programs that automatically improve the performance of some task through experience?

4 As noted later in this chapter, human inputs will also likely be needed to apply the output of the learning algorithm and to assess whether that output remains reliable in light of obvious changing circumstances. In short, complete substitution away from real-time human judgment using AI is implausible given requirements for evaluating, possibly modifying, and implementing the output of learning algorithms.

brain. However, they currently cost hundreds of millions of dollars and have an internal architecture that may still not work well for emulating the human brain. However, he and some others believe that in another 10 years, computers capable of emulating the human brain will likely be available for less than US $1 million. At that point, affordable computers will be quite capable of competing with humans in any task or set of tasks. When that time comes, Parada expects major job losses to emerge. On the other hand, the Canadian AI expert, Yann Lecun, believes that it will take decades to build AI systems that are somewhere near human intelligence (Vance 2018).

Issues and perspectives on AI and employment

Whether or not AI embodying human-level intelligence is achievable in the foreseeable future is a matter of speculation. However, it is clear that AI-enabled machines are doing an increasing number of tasks. Prominent examples exist in the finance industry. One example is automated investment advice or "robo-advising." Many established Wall Street firms, as well as startups focused on financial technology, are offering computerized services that manage asset portfolios. To date, robo-advising has focused on portfolio management, as opposed to more complex and individual-specific tasks such as estate and tax planning. To be sure, capabilities are emerging for versions of robo-advisors that are capable of providing advice on more complex issues.

Even if robo-advising and other manifestations of AI become substantially more sophisticated in their ability to solve human problems, it may still be the case that this development creates a net increase in the demand for labour, albeit for workers possessing different skills from those suffering a decrease in demand. Roe (2018) cites the views of a number of executives regarding the likely impact of AI on employment. Those views are consistent with long, historical experience. That is, the evolution and adoption of AI will primarily change the mix of skills demanded. Indeed, it is more likely to encourage a net increase in the demand for labour rather than a decrease. As an example, Roe discusses the opinion of Rachel Russell, the executive director of corporate strategy for Allegis Group, an employment company specializing in skilled professionals. She argues that while some jobs will certainly be lost as AI takes on skills formerly done by humans, new jobs will emerge. She cites a number of positions that are already developing around AI, such as AI trainers, individuals to support data science and capabilities related to modeling, computational intelligence, machine learning, mathematics, psychology, linguistics, and neuroscience.

The potential for AI to increase the overall demand for labour is related, in part, to the potential productivity benefits of AI adoption. To the extent that a growing use of AI reduces the costs of production of a wide range of goods and (increasingly) services, it effectively increases the real incomes of consumers, other things constant. With higher real incomes, consumers can buy more goods and services, which, in turn, should increase the demand for inputs, including labour, needed to produce increased output.

Frey (Atkinson and Frey, 2019, April 1) argues, without offering evidence, that the short-run productivity benefits of AI will be modest and may not offset the effect of substituting AI for human labour. On the other hand, Atkinson (Atkinson and Frey, 2019, April 1) asserts that automation, whether from AI algorithms or computer-aided machine tools, has not yet led to job losses. He refers to the period from 1997 to 2015, which was a boom time for information technology-led productivity growth. Atkinson points out that productivity growth during this period was accompanied by a growth in labour hours.[5]

There is no reason to think that the productivity benefits from AI adoption will be significantly smaller than from the adoption of earlier innovations. The empirical evidence in this regard is that the adoption of new technology explains much of the variation observed in per capita GDP changes across countries and over time. In this regard, Crespi, Chiara, Haskel, and Slaughter (2008) found that as much as 50 percent of total factor productivity growth arises from the flow of knowledge across firms. In a similar vein, Parente and Prescott (2002) showed that relatively small differences in rates of technological adoption are associated with relatively large disparities in country levels of income.

As is the case with all new technologies, AI will create an increase in the demand for skills that are complementary to the new technology. Increased demand for labour with skills that are complements, as opposed to substitutes, for AI will arise partly from new activities made possible by AI, as well as activities that AI makes much cheaper to carry out. Lecun argues that the major contribution of AI is the development of predictive models (Vance, 2018). Agrawal (2018) concurs that the transformative economic contribution of AI is that it lowers the cost of prediction. As the cost of prediction drops, society will use more of it for traditional prediction purposes, such as inventory management. Society will also start using prediction models to solve problems that haven't been historically thought of as prediction problems. He offers the example of autonomous driving

5 Acemoglu and Restrepo (2017) provide some contrary evidence in their finding that the adoption of robots reduced employment and wages in local labour markets.

where trained AI models predict what a "good driver" would do under a variety of circumstances. He notes that as the quality of AI prediction improves and the cost declines, the value of human prediction will fall. However, the value of judgment in using predictions and implementing activities based on predictions will increase. This perspective highlights the relevance of viewing occupations in terms of the tasks carried out when evaluating the likely employment effects of AI adoption.

Economic studies of the links between AI and employment focus on the tasks carried out in individual occupations. For example, Brynjolfsson, Mitchell, and Rock (2018) examine 964 occupations in the US economy that are broken down into 18,156 specific tasks at the occupational level. They then classify each specific task as being more or less susceptible to machine learning. They conclude that the scope of tasks that are susceptible to machine learning is relatively constrained. Furthermore, the variance of the susceptibility to machine learning at the occupational level is considerably lower than at the task level. This is because job bundling of tasks provides some diversification with respect to machine learning exposure. Many occupations have several tasks that are highly susceptible to being done through machine learning bundled with tasks that have low susceptibility. What one should expect is that organizations will reorganize over time so that humans have more responsibility for tasks that have low susceptibility to machine learning. Increased task specialization is a reason to expect that AI will primarily alter the nature of what workers do at their jobs rather than automating away large portions of the labour force.

Arntz, Gregory, and Zierahn (2016) estimate the automatability of jobs for 21 OECD countries based on a task-based approach taking into account the heterogeneity of workers' tasks within occupations. Overall, they find that, on average, across the 21 OECD countries, less than 10 percent of jobs are automatable. That is, most jobs embody tasks that are not readily automatable by computerization. Furthermore, even if new technologies are introduced, workers can adjust to changing technological endowments by switching tasks.

Nedelkoska and Quintini (2018) review several other recent studies that estimate the share of jobs that are at risk of automation. These studies show that there is considerable variation in the tasks involved in jobs that have the same occupational title and that accounting for this variation is essential for gauging the extent of the risk. The studies they cite put the share considerably below Frey and Osborne's (2013) estimate that 43 percent of jobs in the US are at high risk of being automated. Specifically, the estimates cluster in the high single digits. Their study attempts to account for changes that jobs will undergo as a result of automation, as well as the role of training in helping workers transit to new career opportunities.

Based on survey data from a sample of 32 OECD countries, Nedelkoska and Quintini (2018) estimate that about 14 percent of workers may see their job tasks being entirely restructured or their jobs significantly downsized. They argue that their estimates based on job-specific information are both smaller and more reliable than estimates based on occupational titles. They also caution that underlying assumptions may result in their study overestimating the labour market impact of automation. Specifically, their study abstracts from the possibility that automation will bring about new jobs. It also abstracts from barriers to the adoption of AI including regulations on the dismissal of workers.

Studies of the diffusion of new technologies highlight the relatively slow rates of adoption of those technologies after they are first introduced. For example, Comin and Hobjin (2008) analyzed data on the diffusion of 15 technologies in 166 countries from 1820 to 2003. They found that, on average, countries have adopted technologies 47 years after they were first introduced. To be sure, there is substantial variation across countries and technologies. By way of illustrating this later point, for railroads, it took about a century before they were adopted in half of the countries in the sample. For personal computers and the internet, it took less than 15 years for half of the countries in the sample to adopt those innovations.

Mulder, de Groot and Hofkes (2003) identify several factors that slow the rate at which innovations are adopted by potential users. One is the combination of uncertainty surrounding the net benefits of adopting the innovation combined with the sunk costs of adoption. This combination creates an "option value" in waiting for more information about the potential net benefits. A second factor is the potential for rivals to imitate a firm's innovative behaviour, which creates an argument for firms to postpone the adoption of innovation. A third is the improvement over time in the performance of new technologies, as well as reductions in their price due to efficiency gains in their development and use. A fourth is that the adoption of new technologies destroys the economic rents associated with working with older technologies enjoyed by specific sub-groups in the economy. The latter will often engage in efforts aimed at keeping the old technologies in place in order to protect their economic rents.

Costs and barriers to the adoption of AI are important to consider in any forecast of how AI will affect labour markets. In particular, a relatively slow adoption rate will provide time for at-risk workers to acquire skills that are weaker substitutes for AI. It will also allow future generations of workers to invest in education and training that equips them with skills that are complementary to AI. In this regard, as noted above, experts in the AI field see the emergence and spread of Artificial General Intelligence as likely to be a slow process, in part for the reasons cited by Mulder, de

Groot, and Hofkes (2003). The slow and interrupted growth of AI technology to this point supports this assessment. For example, the first self-driving car was reportedly built in the late 1980s, and the technological insights underlying the self-driving car are much older (Vance, 2018). It was not until 2014 that Google made the first self-driving car capable of passing a state driving test, and we still seem years away from self-driving cars replacing traditional cars to any significant extent.

The term AI was itself coined as far back as 1956 at a conference at Dartmouth University that is considered to herald the birth of AI as a distinct branch of computer science. There have been several periods between 1956 and the present when funding for AI dried up given a perceived lack of progress with the technology and skepticism about its commercial applicability (Vance, 2018). Such interrupted episodes of AI progress might well characterize the future.

Additional caution against overestimating the speed of AI developments is provided by economist Wassily Leontief, who in 1983 was quoted as predicting that AI would displace many people in the following 30 to 40 years creating massive problems of unemployment (Nilsson, 1984). In the same article containing Leontief's prediction, Nilsson (1984) asserts that many AI scientists believe that AI will inevitably equal or surpass human mental abilities—if not in 20 years, then surely in 50. Some 35 years after the publication of Nilsson's article, most AI scientists do not believe they are close to achieving human-like intelligence using AI.

In sum, notwithstanding the optimistic views of some AI experts that this technology will be adopted much more quickly in the future than in the past, historical experience with AI and other General Purpose Technologies offers more confidence that the adoption of ever-more advanced AI systems in the economy will be a relatively slow process.

Concluding comments

The historical experience with General Purpose Technologies is that while they change the mix of skills demanded in the workplace, they do not lead to substantial decreases in overall employment. Indeed, over time, technological change is positively correlated with overall employment for reasons discussed earlier in this essay. Those who argue that the AI experience will be different and that major new government initiatives such as a guaranteed basic income are needed carry a heavy burden of proof. The experience with AI to date suggests that the experience with this new technology will not be much different from the experience with other new technologies when it comes to effects on employment levels.

This is not to say that the future adoption of AI will be identical in all respects to earlier experiences of automation. For example, Nedelkoska and Quintini (2018) argue that the skill set predominantly affected by the continued evolution and adoption of AI will be different from the set predominantly affected by earlier vintages of automation. Specifically, AI puts more low-skilled jobs at risk than previous waves of technological progress in which technology replaced primarily middle-skilled jobs. They also argue that AI compared to earlier automation technologies will create more change in required job skills and tasks.

It is interesting to note that Nedelkoska and Quintini (2018) identify countries located in Northern Europe and North America (including Canada) as scoring lowest on the probability of jobs at risk for automation across the OECD sample of countries. This reflects the smaller share of those economies accounted for by manufacturing, as well as a higher percentage of specialization in cognitive jobs. As DiMatteo discusses in an accompanying essay in this volume, Canada's labour force is likely to decrease over the next few decades. To the extent that the effect of AI on the overall demand for labour is similar to other General Purpose Technologies, the future incorporation of AI technology into the economy combined with a declining labour force may result in a substantial increase in the scarcity of qualified workers rather than the widespread unemployment predicted by doomsayers.

References

Acemoglu, Daron, and Pascual Restrepo (2017). *Robots and Jobs: Evidence from US Labor Markets*. NBER Working Paper No. 23285. National Bureau of Economic Research. <http://www.nber.org/papers/w23285>, as of May 14, 2019.

Agrawal, Ajay (2018). The Economics of Artificial Intelligence. *McKinsey Quarterly* (April). <https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/the-economics-of-artificial-intelligence>, as of May 14, 2019.

Arntz, Melanie, Terry Gregory, and Ulrich Zierahn (2016). *The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis.* OECD Social, Employment and Migration Working Papers No. 189. Organisation for Economic Cooperation and Development. <https://dx.doi.org/10.1787/5jlz9h56dvq7-en>, as of May 14, 2019.

Atkinson, Robert, and Carl Frey (2019, April 1). Will AI Destroy More Jobs Than It Creates Over the Next Decade? Debate. *Wall Street Journal*. <https://www.wsj.com/articles/will-ai-destroy-more-jobs-than-it-creates-over-the-next-decade-11554156299>, as of June 25, 2019.

Bresnahan, Timothy, and Manuel Trajtenberg (1992). *General Purpose Technologies "Engines of Growth?"* NBER Working Paper No. 4148. National Bureau of Economic Research. <https://www.nber.org/papers/w4148>, as of May 14, 2019.

Brynjolfsson, Erik, Tom Mitchell, and Daniel Rock (2018). What Can Machines Learn and What Does It Mean for Occupations and the Economy? *AEA Papers and Proceedings* 108: 43–47. <https://www.cs.cmu.edu/~tom/pubs/AEA2018-WhatCanMachinesLearn.pdf>, as of May 14, 2019.

Carden, Art (forthcoming). A Curse on (Intelligent) Machines? In Steven Globerman (ed.). *Automation and Employment: Will This Time be Different?* The Fraser Institute.

Clifford, Catherine (2017a, July 24). Facebook CEO Mark Zuckerberg: Elon Musk's Doomsday AI Predictions are "Pretty Irresponsible." *CNBC*. <https://www.cnbc.com/2017/07/24/mark-zuckerberg-elon-musks-doomsday-ai-predictions-are-irresponsible.html>, as of May 14, 2019.

Clifford, Catherine (2017b, February 3). Warren Buffet and Bill Gates Think It's "Crazy" to View Job-Stealing Robots as Bad. *CNBC*. <https://www.cnbc.com/2017/02/03/warren-buffett-and-bill-gates-think-its-crazy-to-view-robots-as-bad.html>, as of May 14, 2019.

Comin, Diego, and Bart Hobijn (2008). *An Exploration of Technological Diffusion*. Mimeo. Harvard Business School. <https://www.dartmouth.edu/~dcomin/files/exploration_technology.pdf>, as of May 14, 2019.

Crespi, Gustavo, Criscuolo Chiara, Jonathan Haskel, and Matthew Slaughter (2008). *Productivity Growth, Knowledge Flows, and Spillovers.* NBER Working Paper 13959. National Bureau of Economic Research. <http://www.nber.org/papers/w13959>, as of May 14, 2019.

Di Matteo, Livio (forthcoming). Technological Change, Baby Boomers, Participation Rates, and the Coming Labour Markets. In Steven Globerman (ed.). *Automation and Employment: Will This Time be Different?* The Fraser Institute.

Frey, Carl, and Michael Osborne (2013). *The Future of Employment: How Susceptible Are Jobs to Computerisation?* University of Oxford. <https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf>, as of May 14, 2019.

Knoess, Christopher, Ron Harbour, and Steve Scemama (2016). Prepare Your Workforce for the Automation Age. *Harvard Business Review* (November 23). <https://hbr.org/2016/11/prepare-your-workforce-for-the-automation-age>, as of June 25, 2019.

McCarthy, John (undated). *What is AI? / Basic Questions*. Interview with Professor McCarthy. <http://jmc.stanford.edu/artificial-intelligence/what-is-ai/index.html>, as of May 14, 2019.

Mulder, Peter, Henri de Groot, and Marjan Hofkes (2003). Explaining Slow Diffusion of Energy-Saving Technologies; A Vintage Model with Returns to Diversity and Learning-by-Using. *Resource and Energy Economics* 25: 105–126.

Nedelkoska, Ljubica, and Glenda Quintini (2018). *Automation, Skills Use and Training.* OECD Social, Employment and Migration Working Papers No. 202. Organisation for Economic Cooperation and Development. <https://www.oecd-ilibrary.org/employment/automation-skills-use-and-training_2e2f4eea-en>, as of May 14, 2019.

Nilsson, Nils J. (1984). Artificial Intelligence, Employment and Income. *AI Magazine* 5, 2: 5–14.

Parada, Roberto (2017). You Will Lose Your Job to a Robot—and Sooner Than You Think. *Mother Jones.* <https://www.motherjones.com/politics/2017/10/you-will-lose-your-job-to-a-robot-and-sooner-than-you-think/>, as of May 14, 2019.

Parente, Stephen, and Edward Prescott (2002). *Barriers to Riches.* MIT University Press.

Roe, David (2018, January 9). Why Artifical Intelligence Will Create More Jobs Than It Destroys. *CMS Wire.* <https://www.cmswire.com/digital-workplace/why-artificial-intelligence-will-create-more-jobs-than-it-destroys/>, as of May 14, 2019.

SAS (undated). *Artificial Intelligence: What It Is and Why It Matters.* Web page. SAS. <https://www.sas.com/en_us/insights/analytics/what-is-artificial-intelligence.html>, as of May 14, 2019.

West, Darrell (2018, October 4). What is Artificial Intelligence? *A Blueprint for the Future of AI.*

Brookings Institution. <https://www.brookings.edu/reserach/what-is-artificial-intelligence/>, as of May 14, 2019.

Vance, Ashlee (2018, May 18). How We Got Here. *Bloomberg Businessweek.* <https://www.scribd.com/article/379513106/How-We-Got-Here>, as of May 14, 2019.

About the author

Steven Globerman

Steven Globerman is Resident Scholar and Addington Chair in Measurement at the Fraser Institute as well as Professor Emeritus at Western Washington University. Previously, he held tenured appointments at Simon Fraser University and York University and has been a visiting professor at the University of California, University of British Columbia, Stockholm School of Economics, Copenhagen School of Business, and the Helsinki School of Economics. He has published more than 150 articles and monographs and is the author of the book *The Impacts of 9/11 on Canada-U.S. Trade* as well as a textbook on international business management. In the early 1990s, he was responsible for coordinating Fraser Institute research on the North American Free Trade Agreement. He earned his BA in economics from Brooklyn College, his MA from the University of California, Los Angeles, and his PhD from New York University.

Acknowledgments

The author thanks Sonia Arrison and Finn Poschmann for very thoughtful and helpful comments on an earlier draft.

3. Demographics, Technological Change, Participation Rates, and Canada's Future Labour Shortage

Livio Di Matteo

Introduction

The business media is rife with warnings about automation—primarily driven by technological change, artificial intelligence (AI), and machine learning—leading to dramatic changes in the labour markets of developed countries (Robertson, 2019). Media reports often warn of large net job losses from a new era of automation with a corresponding need for government initiatives such as a guaranteed annual income to take care of those rendered unemployable by technological change (see Noonan, 2017).

Contrary to warnings about a growing unemployment problem, this essay highlights the potential for a growing scarcity of labour in Canada. Specifically, a slowing population growth rate and a declining labour force participation rate due to retiring baby boomers and an aging population will reduce labour force growth rates over the next few decades. Furthermore, historical experience suggests that technological change primarily alters the mix of employment while promoting faster economic growth, which also creates new jobs. Hence, it seems unlikely that technological change will result in a decline in the aggregate demand for labour. Indeed, rather than facing a future unemployment crisis, Canada is more likely to face a prolonged period of labour scarcity.

The labour force and employment growth: Historical experience and projections

In the 1990s, the effects of recessions and technological change spawned numerous alarming studies about the rise of machines, technological worker displacement, and the end of work. Rifkin (1995) maintained that the spread of information technology would eliminate millions of jobs in manufacturing, agriculture, and the service sectors leading to the decline of private and public sector employment and a rise in voluntary, community-based employment. Yet both public and private sector employment has continued to expand in Canada and around the world. Indeed, long-run technological change appears to create more jobs than are destroyed as has been documented in one study of census results for the United Kingdom since 1871 (Stewart, De, and Cole, 2015).

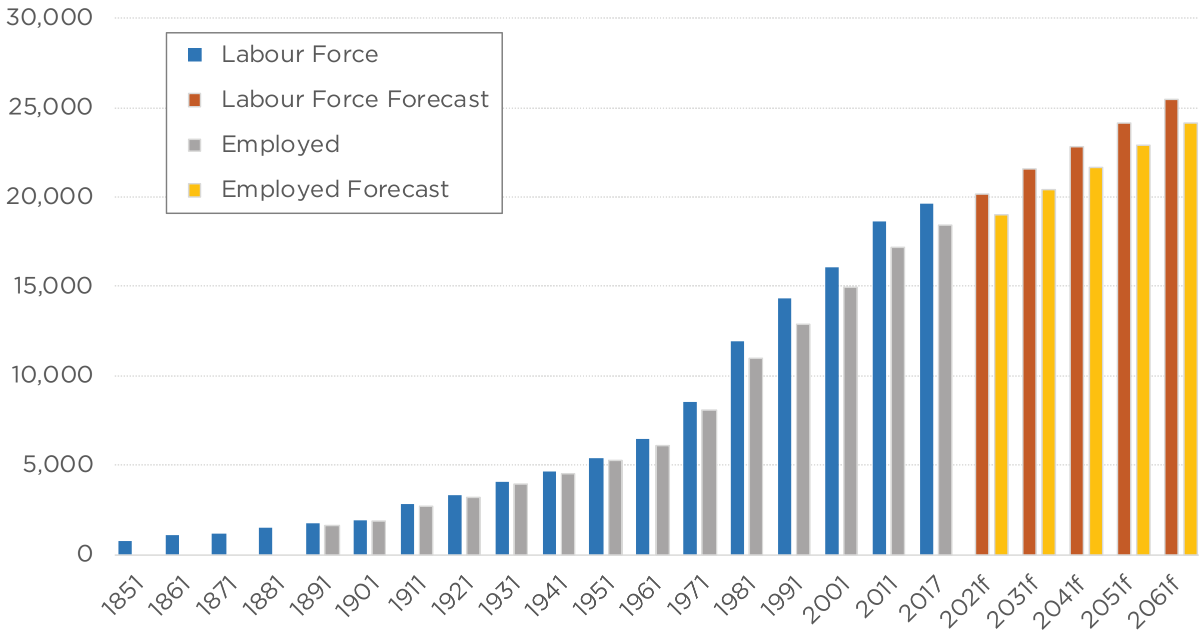
The United Kingdom was the world's first industrial nation, so its experience is informative. Over the long run, the United Kingdom has experienced increases in both employment and the labour force. Stewart, De, and Cole (2015) argue that the technology debate is skewed towards the discussion of job destruction when, in fact, technological change is also accompanied by substantial job creation. Using census records on employment in England and Wales since 1871 and Labour Force Survey Data from 1992, the authors show major declines in occupations such as agricultural labourers, washers, launderers, telephonists, and telegraph operators both in absolute numbers and as a share of employment. At the same time, however, other occupations show increasing employment. They include accountants, bar staff, hairdressers, and other services.

As figure 1 illustrates, the picture is similar for Canada. Between 1851 and 2017, in tandem with a population that grew from 2.4 to 35.2 million, a 15-fold increase, estimates show that the Canadian labour force grew from 762,000 to 19.7 million people, a 26-fold increase. Employment data is available from 1891. It shows that from 1891 to 2017, employment in Canada grew from 1.6 to 18.4 million, a 12-fold increase, while over the same time span the labour force also increased—from 1.7 to 19.7 million, also a 12-fold increase.

Figure 1 also provides simple projection estimates for labour force and employment to 2061 based on applying average annual growth rates[1] starting from 2017 as taken from the *27th Actuarial Report on the Canada Pension Plan* (OSFI, 2017). The results reported in figure 1 show that both

[1] The annual percent increases used to calculate labour force are as follows: from 2017 to 2021: 0.683; from 2021 to 2035: 0.643, and from 2035 to 2075: 0.55. The annual percent increases used to calculate employment are as follows: from 2017 to 2021: 0.8; from 2021 to 2035: 0.7, and from 2035 to 2077: 0.55.

Figure 1: Labour Force and Employment in Canada (in thousands), from 1851 to 2017 with Forecasts to 2061



Sources: Denton and Ostry (1961); Statistics Canada (various years), *Historical Statistics of Canada*; Statistics Canada (1973 and 1989); Statistics Canada, Series v102029212 Canada [11124] Table 14100297, Labour force (Persons), Total, all occupations; Both sexes Series v102029368 Canada [11124] Table 14100297, Employment (Persons), Total, all occupations, Both sexes.

the labour force and employment are expected to continue growing after 2017, but the rate of growth slows between 2017 and 2061 compared to the rise between 1961 and 2017. The labour force grew from 6.504 million in 1961 to 19.663 million in 2017. It is forecast to reach 25.490 million by 2061. Employment was 6.055 million in 1961 and grew to 18.416 million in 2017. The forecast shown in figure 1 projects employment to reach only 24.716 million by 2061.

From 1961 to 2017, the implied annual growth rate of Canada's labour force was nearly 2 percent, whereas the projected growth from 2017 to 2061 is about 0.6 percent. Employment also grew at an annual implied growth rate of about 2 percent from 1961 to 2017. However, for the 2017 to 2061 period, its expected growth rate is 0.7 percent. Moreover, since employment is projected to grow at a slightly higher rate than the labour force from 2017 to 2061, the unemployment rate is expected to fall from 6.3 percent in 2017 to 5.2 percent by 2061 (OSFI, 2017: table 44, p. 93).

The expected decline in the growth rate of Canada's labour force reflects expectations of a relatively slow growth rate for Canada's population. Canada's population grew at an average annual rate of around 1.1 percent from 2007 to 2016. According to Statistics Canada's current medium growth projection, the annual population growth rate to 2063 is projected to be a much lower 0.7 percent (see Jackson, Clemens, and Palacios, 2017). It also reflects an aging of the population.[2] All other things given, labour force participation growth rates tend to decline as the share of the elderly in the population increases.

Along with employment growth that accompanies the expansion in the overall labour force during periods of technological progress and development, the composition of employment has also changed. For example, in 1921, agriculture still accounted for nearly one-third of all employment (though down from 50 percent in 1871) whereas by the early 21st century, agriculture's share of employment was below two percent (Statistics Canada, 2011). Overall, the last 150 years has seen a shift from goods production to services as the dominant source of employment.

In the near future, despite continuing concerns about the negative impact of new technologies on employment, the projection is that there will be increasing labour shortages, particularly for skilled workers. To the extent that individuals are less likely to work after age 55, the demographic impact of the baby boom is likely to contribute to labour scarcity, as that population bulge eventually retires in unprecedented numbers with smaller cohorts behind it.

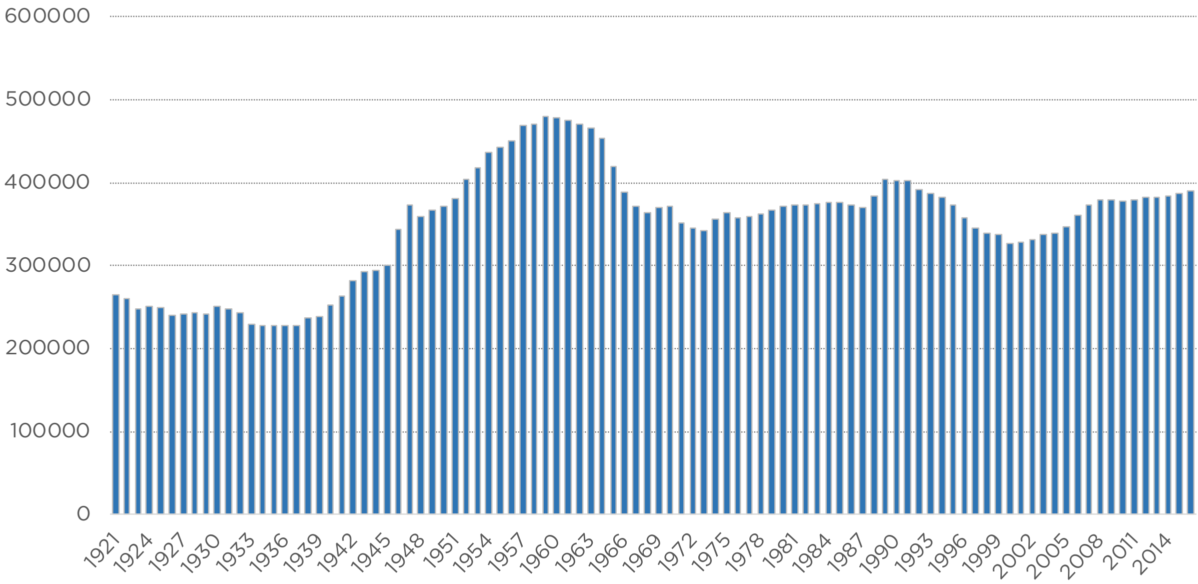
The post-war baby boom and its consequences

The Canada's "baby boom" refers to the demographic bulge of Canadians born from 1947 to 1966.[3] Figures 2 and 3 outline the size of the baby boom by showing both total births and the birth rate (the ratio of births per 1,000 population). From 372,589 births in 1947, total births in Canada rose to a peak of 479,275 in 1959 before starting a decline to 387,710 in 1966, after which total births levelled off. Births began rising from a low of 20.63

[2] From 2010 to 2063, the share of seniors in Canada's population is projected to increase from slightly under 15 percent to over 25 percent (see Jackson, Clemens, and Palacios, 2017).

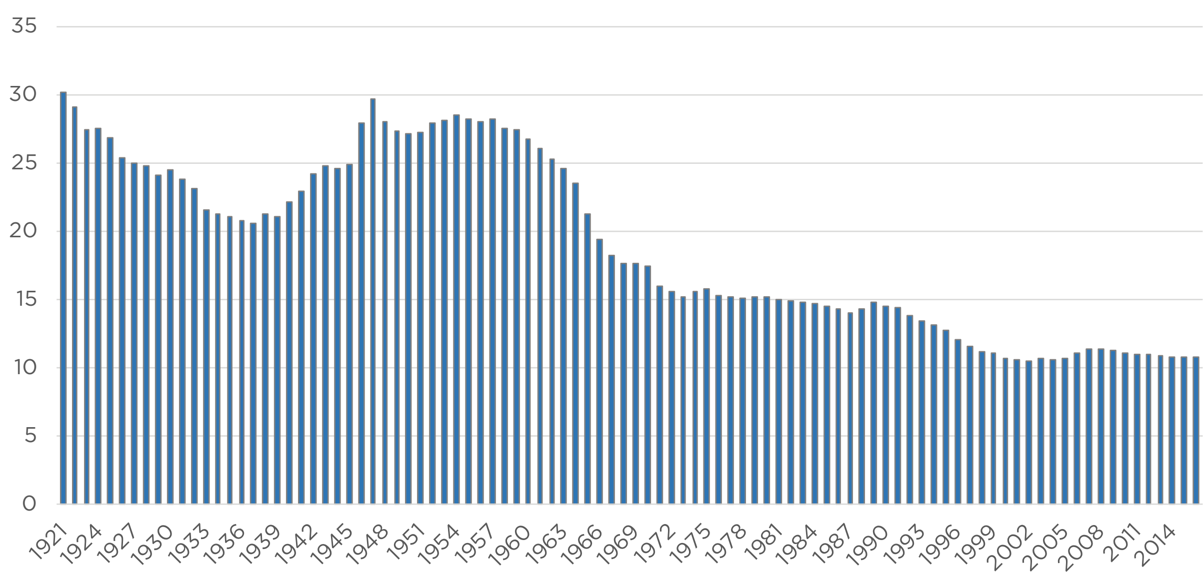
[3] The baby boom marked the post-World War II demographic experience of four countries in particular—the United States, Canada, Australia, and New Zealand. Countries in Western Europe experienced more mitigated "boomlets." For the United states, the baby boom denotes births from 1946 to 1964. See Encyclopedia Britannica (2019) and Foot and Stoffman (1996: 19).

Figure 2: Total Births in Canada, 1921 to 2016



Sources: Statistics Canada (1921 to 1970), *Historical Statistics of Canada*, Series B1-14; Statistics Canada (1971 to 2016), Series v470763 Canada [11124] Table 17100016, Both sexes (Persons).

Figure 3: Births Per 1,000 Population in Canada, 1921 to 2016



Sources: Statistics Canada (1921 to 1970), *Historical Statistics of Canada*, Series B1-14; Statistics Canada (1971 to 2016), Series v470763 Canada [11124] Table 17100016, Both sexes (Persons).

per 1,000 population in 1937 during the Great Depression to 29.69 per 1,000 in 1947. The birth rate began declining in about 1954 and reached 19.37 per 1,000 population in 1966. The birth rate has continued to decline after dropping to 10.75 per 1,000 population in 2016.

A key characteristic of the baby boomer cohort is its sheer size and the demographic impact it has had, and continues to have, on labour markets, real estate markets, housing construction, financial investment, retail, education, health care, and ultimately the funeral industry. For example, as the early baby boomers turned 20 years old in 1967, the first of them entered the housing market, which generated both a surge in home building and apartment shortages. The result was the implementation of rent control policies in all 10 provinces (Foot and Stoffman, 1996: 31). Those early baby boomers turned 65 in 2012 and, as they become a growing share of an older population, one can expect increased demand for health care services, as well as rising health care spending to meet this demand.[4]

The baby boom also had an impact on labour markets. Specifically, an increased labour supply was also accompanied by increases in participation rates by women. As baby boomers entered the labour force, there was an increase in labour force growth, sometimes at a pace of more than three percent annually. Indeed, an increase in the natural rate of unemployment was documented for the United States in the 1960s and 1970s coinciding with the entry of the baby boomers to the labour force (Munnell, 2014). At the same time, this expansion in labour supply was a driving factor for economic growth, especially given the post-1970 slowdown in productivity growth (see Cross, 2015).

In the wake of the so-called "baby bust" era spanning the mid 1960s to the mid 1970s, labour force growth slowed and corporate structures became clogged with large numbers of mid-career people and fewer entry level employees, which led organizations to restructure to become more lateral than hierarchical. Self-employment also grew as those at the tail end of the baby boom found promotion opportunities more limited and began to branch out on their own (see Foot and Stoffman, 1996: 79).

Those in the middle of the baby boom generation are now in their mid 60s and there is considerable interest in the impact of population aging and looming retirements on the labour market in Canada. For the United States, the aging of the population has reduced labour force participation since 2000, and the decline in labour force participation is expected to continue into the near future (Munnell, 2014). For Canada, the proportion of the population aged 65 and older has been increasing and is

4 While health expenditures do rise with age, the impact of an aging population on health spending to date has been somewhat muted.

expected to continue to do so as the baby boomers age, contributing to a decrease in overall labour force participation rates.

Labour force participation

Demographic factors such as an aging population are one reason why labour force participation rates decline. Other reasons include workers becoming discouraged in the wake of job losses after a recession, youth staying in school longer and delaying their labour market entry, lower rates of educational attainment that generate a mismatch with new jobs and increasing numbers of individuals who are sick or disabled.[5] Indeed, disability rates for males and females in Canada have been rising since the late 1990s (see OSFI, 2017: chart 11, p. 128).

According to a Statistics Canada study by Fields, Uppal, and LaRochelle-Côté (2017), overall labour force participation in Canada has been declining since 2007, most noticeably in the wake of the 2008-09 economic downturn. At the same time, there has been an increase in labour force participation by older Canadians. In 2016, individuals aged 55 years and over accounted for 36 percent of the working age population—the highest since comparable statistics began to be compiled in 1976—and this proportion is expected to reach 40 percent by 2026.[6] From 1996 to 2015, the labour force share of individuals aged 55 years and older increased from 24 percent to 38 percent—across all levels of education. This increase was driven in part by a decline in employer-sponsored pensions that were more common decades ago, and low real interest rates. The latter reduce the returns to savings that help fund retirement.

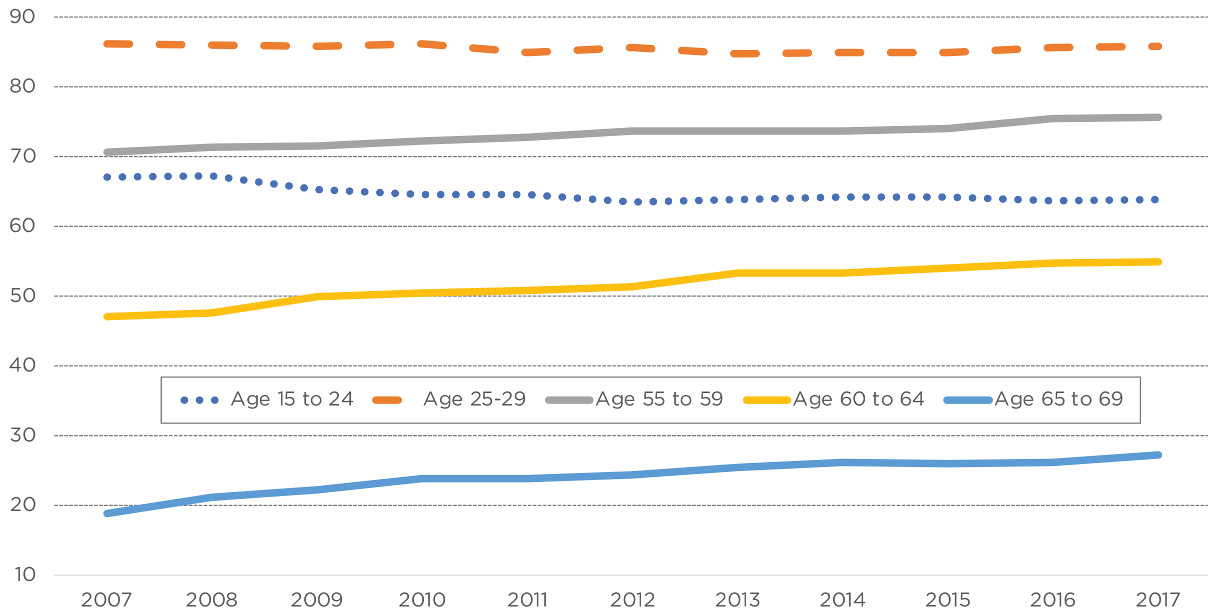
However, Fields, Uppal, and LaRochelle- Côté note that the increase in participation rates for those 55 years and older will not fully offset the negative effects of the declining share of the core working age and youth population, so that overall participation rates are expected to decline.[7] From 2007 to 2016, the overall participation rate declined by 2 percentage points. If the age structure of the population had stayed the same as a decade earlier, one would have expected the participation rate to have

5 For another discussion of the determinants of labour force participation, see Amadeo (2019).

6 The growing proportion of workers aged 55 years and older has been termed "the rise of the perennial" with approximately one-fifth of jobs being held by this demographic. For a more detailed description of the perennial workforce see Nazareth (2018).

7 Indeed, some forecasts show total labour force participation rates going from 66 percent in 2017 to 63 percent by 2030. (See OFSI, 2017: table 44, p. 93).

Figure 4: Labour Force Participation Rates in Canada (%) by Selected Age Groups, 2007 to 2017



Sources: Statistics Canada, Series v2461246 Canada [11124] Table 14100018; Statistics Canada, Participation rate (Percentage), Both sexes, 15 to 24 years, Series v2461255 Canada [11124] Table 14100018; Statistics Canada, Participation rate (Percentage), Both sexes, 25 to 29 years, Series v2461261 Canada [11124] Table 14100018; Statistics Canada, Participation rate (Percentage), Both sexes, 55 to 59 years, Series v2461262 Canada [11124] Table 14100018; Statistics Canada, Participation rate (Percentage), Both sexes, 60 to 64 years, Series v2461264 Canada [11124] Table 14100018; Statistics Canada, Participation rate (Percentage), Both sexes, 65 to 69 years.

increased by 1 percentage point. In this regard, using data from Canada's Chief Actuary, Jackson, Clemens, and Palacios (2017) forecast that from 2017 to 2063, Canada's labour force participation rate will fall from about 65 percent to 61 percent.

Figure 4 plots labour force participation rates between 2007 and 2017 for specific demographic groups—individuals of both sexes aged 15 to 24, 25 to 29, 55 to 59, 60 to 64, and 65 to 69. Between 2007 and 2017, the participation rate for individuals aged 15-24 declined from 67 to 63.9 percent, while that for those aged 25 to 29 declined slightly from 86.1 to 85.9 percent. However, the participation rates of older workers soared between 2007 and 2017. For those aged 55 to 59 years, the rate grew from 70.6 to 75.7 percent, while for those aged 60 to 64 it went from 47 to 55 percent. More interesting, the participation rate for those aged 65 to 69 went from 18.8 to 27.3 percent.

This difference in behaviour between younger and older demographic groups is a function of economic conditions. The onset of the Great Recession harmed the employment prospects of those looking for entry-level positions, which contributed to the poor participation rates of those below age 30. At the same time, the fall in interest rates since 2008 has reduced the cost of borrowing and, for the purposes of investing in human capital, it meant that younger workers could acquire more post-secondary education than in the past, resulting in longer stays in school. As well, the fall in interest rates reduced the rate of return on secure investments. The lower return on investments combined with the fall in stock markets in 2008-09 delayed retirement for many older workers and brought others back into the labour market, especially those aged 65 and older.

While the participation rates of older workers have been increasing, overall participation rates have fallen—especially among youth in the wake of the Great Recession. Indeed, the participation rate of individuals aged 15 to 24 was 67.3 percent in 2008, but in 2017 it was 63.9 percent. Meanwhile, the participation rate of those aged 25 to 29 has stayed practically the same at 86 percent.[8] As well, while about 91 percent of prime age males (those aged 25 to 54) are in the labour force, the rate for females of the same age is still only about 83 percent (Poloz, 2018). According to Bank of Canada Governor Stephen Poloz, returning youth participation rates to what they were prior to the Great Recession, further boosting female participation rates closer to that of males, increasing the employment rates of indigenous peoples, and speeding up the labour force integration of recent immigrants would also help alleviate the prospect of future labour shortages (Poloz, 2018). However, it is unclear to what extent these developments will transpire.

Foot and Venne (2011) maintain that with increasing life expectancy, individuals will work longer and firms will respond with creative policies such as partial retirement strategies that will also help blunt the impact of an aging population. Indeed, the increased labour market participation by individuals aged 55 years and over in the last decade likely represents the leading edge of this trend. Additional policies to boost the retraining and productivity of older workers, especially to help them use new information technologies to take advantage of new economic opportunities, may mitigate the effects of labour shortages in the short term. Whether such government and private sector initiatives will be sufficient to offset the

8 The labour force participtation rate for those aged 55 to 59 over the same period grew from 71.3 to 75.7 percent and for those aged 60 to 64, it grew from 47.6 to 55.0 percent (Statistics Canada, Participation Rates [Both Sexes], Series v2461246, v2461255, v2461261, v2461262, Table 14100018).

powerful demographic forces reducing labour force participation rates as outlined earlier again seems difficult to predict.

Changing the occupational mix

While there is the anticipation that the retirement of the baby boomers will lead to a labour shortage, there may also be some mitigating factors that will make the transition and adjustment more gradual and less abrupt. First, the impact of labour-saving technology can be expected to have some effect, particularly in the service sector industries. Indeed, it has been estimated that globally, technological change could displace about 15 percent of employment by 2030, but at the same time, this will be offset by employment creation provided workers acquire the skills that can move them to new jobs (International Labour Organization, 2018).

At the same time, one can expect to see increases in demand for certain types of labour. For example, the Canadian Occupational Projection System has a forecast for occupations that will see the greatest growth between 2017 and 2026 (Employment and Social Development Canada, 2017). Occupations with above average growth rates include health care, computer system design and related services, support services for mining, oil and gas extraction, social assistance, legal, accounting and other professional services, arts and entertainment, and food services.[9] This means that even as technological change displaces workers in some industries, it creates changes in the mix of occupations demanded that could actually increase employment in other industries.[10]

Conclusion

Contrary to popular belief, the history of technological change has been marked by increases in total employment in the long run, notwithstanding short-term displacements of labour. Canada's labour market future can still be expected to see continued employment growth, though at lower rates than in the previous half century. Slower employment growth will primarily reflect demographic changes and associated changes in labour force participation rates. Moreover, the aging of the labour force and even-

9 These occupations are expected to have a growth rate in excess of an economy-wide average of 0.9 percent.

10 As well, there can be specific shortages in areas such as trades due to external shocks such as weather disasters that ramp up the demand for rebuilding purposes. (See Burke, 2018, December 30).

tual retirement of the baby boomers combined with the creation of new types of jobs will actually come together to generate a scarcity of labour. Indeed, all other things constant, Canada may be facing an extended period of labour scarcity that will see continued low unemployment rates.

References

Amadeo, K. (2019, February 6). Labour Force Participation Rate and Why It Hasn't Improved Much. *The Balance*. <https://www.thebalance.com/labor-force-participation-rate-formula-and-examples-3305805>, as of June 25, 2019.

Burke, David (2018, December 30). Who Will Rebuild after a Climate Disaster as Workers Retire and Weather Worsens? *CBC News*. <https://www.cbc.ca/news/canada/nova-scotia/jobs-labour-market-climate-change-1.4944803>, as of June 25, 2019.

Cross, Philip (2015). *Is Slow Growth the New Normal for Canada*? Fraser Institute. <https://www.fraserinstitute.org/sites/default/files/is-slow-growth-the-new-normal-for-canada.pdf>, as of June 25, 2019.

Denton, Frank T. and Sylvia Ostry (1961). *Historical Estimates of the Canadian Labour Force*. Census Monographs. Dominion Bureau of Statistics. <http://publications.gc.ca/collections/collection_2017/statcan/CS99-549-1967-eng.pdf>, as of June 25, 2019.

Employment and Social Development Canada (2017). *Canadian Occupational Projection System. Job Openings 2017-2026*. Government of Canada. <http://occupations.esdc.gc.ca/sppc-cops/l.3bd.2t.1ilshtml@-eng.jsp?lid=17&fid=1&lang=en>, as of June 25, 2019.

Encyclopedia Britannica (2019). *Baby Boom Population Trend*. Encyclopedia Britannica. <https://www.britannica.com/science/baby-boom>, as of June 25, 2019.

Fields, Andrew, Sharanjit Uppal, and Sébastien LaRochelle-Côté (2017). *The Impact of Aging on Labour Market Participation Rates.* Insights on Canadian Society. Statistics Canada. <https://www150.statcan.gc.ca/n1/en/pub/75-006-x/2017001/article/14826-eng.pdf?st=BJ_FZSko>, as of June 25, 2019.

Foot, David K., with Daniel Stoffman (1996). *Boom Bust and Echo: How to Profit from the Coming Demographic Shift*. McFarlane Walters and Ross.

Foot, David K., and Rosemary A. Venne (2011). The Long Goodbye: Age, Demographics, and Flexibility in Retirement. *Canadian Studies in Population* 38, 3-4 (Fall/Winter): 59–74. <https://www.edwards.usask.ca/faculty/Rosemary%20Venne/files/17817-41058-2-PB.pdf>, as of June 26, 2019.

International Labour Organization [ILO] (2018). *The Impact of Technology on the Quality and Quantity of Jobs*. Issue Brief No. 6. Global Commission on the Future of Work, ILO. <https://www.ilo.org/wcmsp5/groups/public/---dgreports/---cabinet/documents/publication/wcms_618168.pdf>, as of June 26, 2019.

Jackson, Taylor, Jason Clemens, and Milagros Palacios (2017). *Canada's Aging Population and Implications for Government Finances*. The Fraser Institute. <https://www.fraserinstitute.org/sites/default/files/canadas-aging-population-and-implications-for-government-finances.pdf>, as of June 25, 2019.

Munnell, Alicia H. (2014). The Impact of Aging Baby Boomers on Labour Force Participation. Number 14-4 (February). Center for Retirement Research at Boston College. <https://crr.bc.edu/wp-content/uploads/2014/02/IB_14-4-508.pdf>, as of June 26, 2019.

Nazareth, Linda (2018). *Work Is Not a Place: Our Lives and Our Organizations in the Post-Jobs Economy*. BookBaby.

Noonan, David (2017, July 18). Is Guaranteed Income for All the Answer to Joblessness and Poverty? *Scientific American*. <https://www.scientific-american.com/article/is-guaranteed-income-for-all-the-answer-to-joblessness-and-poverty/>, as of June 26, 2019.

Office of the Chief Actuary [OSFI] (2017). *27th Actuarial Report on the Canada Pension Plan as at December 31 2015*. Office of the Superintendent of Financial Institutions Canada.

Poloz, Stephen (2018). *Today's Labour Market and the Future of Work*. Chancellor David Dodge Lecture in Public Finance 2018. Queen's University, Kingston, Ontario. <https://www.bankofcanada.ca/2018/03/todays-labour-market-future-work/>, as of June 26, 2019.

Rifkin, Jeremy (1995). *The End of Work: The Decline of the Global Labor Force and the Dawn of the Post-Market Era.* Putnam Publishing Group.

Robertson, Katie (2019, March 12). How to Navigate Investing in AI, From Someone Who's Done It. *New York Times*. <https://www.nytimes.com/2019/03/02/business/reid-hoffman-ai-investments.html>, as of June 26, 2019.

Statistics Canada (various years). *Historical Statistics of Canada*. Catalogue 11-516-X. Statistics Canada. <https://www150.statcan.gc.ca/n1/pub/11-516-x/3000140-eng.htm>, as of July 2, 2019.

Statistics Canada (1973 and 1989). *Historical Labour Force Statistics, Actual Data, Seasonal Factors, Seasonally Adjusted Data*. Catalogue 71-201 Annual. Statistics Canada.

Statistics Canada (2011). *Agriculture*. Catalogue number 11-402-X. Government of Canada. <https://www150.statcan.gc.ca/n1/pub/11-402-x/2011000/chap/ag/ag-eng.htm>, as of June 26, 2019.

Stewart, Ian, Debapratim De, and Alex Cole (2015). T*echnology and People: The Great Job-Creating Machine*. Deloitte. <https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/finance/deloitte-uk-technology-and-people.pdf>, as of June 26, 2019.

About the author

Livio Di Matteo

Livio Di Matteo is a Senior Fellow at the Fraser Institute and Professor of Economics at Lakehead University in Thunder Bay, Ontario, where he specializes in public policy, health economics, public finance, and economic history. His recent work examines health care spending and its sustainability. As well, he conducts research on the historical evolution of economic inequality. Di Matteo is a member of the CIHI National Health Expenditure Advisory Panel, the Evidence Network (EvidenceNetwork.ca), and is a contributor to the economics blog, *Worthwhile Canadian Initiative.* He has been listed in *Canadian Who's Who* since 1995 and holds a Ph.D. from McMaster University, an M.A. from the University of Western Ontario, and a B.A. from Lakehead University.

General acknowledgments

The authors of this collection wish to thank the anonymous reviewers for their comments and suggestions. Any remaining errors are the sole responsibility of the authors. As the researchers have worked independently, the views and conclusions expressed in these papers do not necessarily reflect those of the Board of Directors of the Fraser Institute, the staff, or supporters.

Publishing information

Distribution

These publications are available from <http://www.fraserinstitute.org> in Portable Document Format (PDF) and can be read with Adobe Acrobat® or Adobe Reader®, versions 8 or later. Adobe Reader® DC, the most recent version, is available free of charge from Adobe Systems Inc. at <http://get.adobe.com/reader/>. Readers having trouble viewing or printing our PDF files using applications from other manufacturers (e.g., Apple's Preview) should use Reader® or Acrobat®.

Ordering publications

To order printed publications from the Fraser Institute, please contact:

- e-mail: sales@fraserinstitute.org
- telephone: 604.688.0221 ext. 580 or, toll free, 1.800.665.3558 ext. 580
- fax: 604.688.8539.

Media

For media enquiries, please contact our Communications Department:

- 604.714.4582
- e-mail: communications@fraserinstitute.org.

Copyright

Date of issue

July 2019

ISBN

978-0-88975-558-1

Citation

Globerman, Steven (contributing editor) (2019). T*echnology, Automation, and Employment: Will this Time be Different?* Fraser Institute. <http://www.fraserinstitute.org>.

Supporting the Fraser Institute

To learn how to support the Fraser Institute, please contact

- Development Department, Fraser Institute
  Fourth Floor, 1770 Burrard Street
  Vancouver, British Columbia, V6J 3G7 Canada
- telephone, toll-free: 1.800.665.3558 ext. 548
- e-mail: development@fraserinstitute.org
- website: <http://www.fraserinstitute.org/donate>

Purpose, funding, and independence

The Fraser Institute provides a useful public service. We report objective information about the economic and social effects of current public policies, and we offer evidence-based research and education about policy options that can improve the quality of life.

The Institute is a non-profit organization. Our activities are funded by charitable donations, unrestricted grants, ticket sales, and sponsorships from events, the licensing of products for public distribution, and the sale of publications.

All research is subject to rigorous review by external experts, and is conducted and published separately from the Institute's Board of Trustees and its donors.

The opinions expressed by authors are their own, and do not necessarily reflect those of the Institute, its Board of Trustees, its donors and supporters, or its staff. This publication in no way implies that the Fraser Institute, its trustees, or staff are in favour of, or oppose the passage of, any bill; or that they support or oppose any particular political party or candidate.

As a healthy part of public discussion among fellow citizens who desire to improve the lives of people through better public policy, the Institute welcomes evidence-focused scrutiny of the research we publish, including verification of data sources, replication of analytical methods, and intelligent debate about the practical effects of policy recommendations.

About the Fraser Institute

Our mission is to improve the quality of life for Canadians, their families, and future generations by studying, measuring, and broadly communicating the effects of government policies, entrepreneurship, and choice on their well-being.

Notre mission consiste à améliorer la qualité de vie des Canadiens et des générations à venir en étudiant, en mesurant et en diffusant les effets des politiques gouvernementales, de l'entrepreneuriat et des choix sur leur bien-être.

Peer review—validating the accuracy of our research

The Fraser Institute maintains a rigorous peer review process for its research. New research, major research projects, and substantively modified research conducted by the Fraser Institute are reviewed by experts with a recognized expertise in the topic area being addressed. Whenever possible, external review is a blind process. Updates to previously reviewed research or new editions of previously reviewed research are not reviewed unless the update includes substantive or material changes in the methodology.

The review process is overseen by the directors of the Institute's research departments who are responsible for ensuring all research published by the Institute passes through the appropriate peer review. If a dispute about the recommendations of the reviewers should arise during the Institute's peer review process, the Institute has an Editorial Advisory Board, a panel of scholars from Canada, the United States, and Europe to whom it can turn for help in resolving the dispute.

Editorial Advisory Board