Catalogue no. 11-626-X — 2020024 - No. 126
ISSN 1927-503X
ISBN 978-0-660-36166-6

Economic Insights

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Release date: November 2, 2020

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The Effect of Robots on Firm Performance and Employment

Jay Dixon

This article examines the impact of robot investment on firm performance and employment at the enterprise level. The analysis is based on a data set on robot purchases derived from data on imports, combined with data from National Accounts Longitudinal Microdata File (NALMF) and from the Workplace and Employee Survey (WES). Investments in robots have been concentrated in the manufacturing sector, with the automotive industry making particularly large investments prior to the year 2008. Recent investments have been in robots with a broader range of capabilities performing tasks in a broader range of industries. Robots raise firms' productivity, but they are associated with the firm hiring more, rather than fewer workers. Robots appear to change the types of human skills firms require, however.

Introduction

Fears of artificially intelligent machines have lingered in the human imagination for thousands of years. Millennia ago, Greek myths like those of Talus or Pandora told of artificial beings created by the gods wreaking chaos and destruction when they are sent among mortals on Earth. Science fiction has picked up this ancient theme in the last century: Karel Čapek's 1920 play *R.U.R.: Rossum's Universal Robots* implanted the word "robot" in the global lexicon and imagination. Named for the Czech word *robota* (the serfs' obligation of labour to their feudal masters) Rossum's artificially intelligent automatons eventually revolt and exterminate their human masters.[1]

Recent breakthroughs in AI have focussed attention on robots as potential job killers. Autor and Salomons (2017) coined the term *robocalypse* to describe a vision of the future "where the endless march of technology ultimately immiserates labor". Some observers have argued that the robocalypse is nearer than society is prepared for, and advocate policy interventions to slow the process of robot adoption. Other observers are sanguine, believing that robots are little different from previous waves of automation that created enough tasks for humans to compensate for the workers new machines displaced. Although switching workers to other tasks was often fraught and not all of them could benefit, past automation generated for labour as a whole a roughly constant share of rapidly increasing output.

Whether robotic automation is playing out like its non-robotic predecessors or heralding the robocalypse is ultimately an empirical question. The study introduced in this article uses newly constructed firm-level administrative data for the years 1996-2017 to examine what kind of Canadian firms are investing in robots and what happens to their workers when they do. It shows that robots investment has been concentrated in certain manufacturing industries, but is now spreading to other areas of the economy. Firms adopting them tend to hire more, not fewer workers. But they hire fewer managers to oversee them, and tasks and responsibilities shift within the firm. Turnover increases for all types of workers, but middle-skilled workers appear to fare worse than both their high and low skilled counterparts.

1. Though the play was originally Czech, its sub-title appeared in English. Čapek's robots were created from synthetic human tissue and were not mechanical.

Are these the droids we're looking for?

The paucity of suitable data makes it difficult to study the impact of robots on the economy. Ambiguity over what machines should be considered robots is part of the problem. Roboticists characterize them as machines that are able to sense changes in their environment and autonomously formulate complex responses. According to the International Federation of Robotics (IFR), a global association of national robotics industry associations, there are two types of robots its affiliated firms sell commercially: *industrial* and *service*. Industrial robots are "automatically controlled, re-programmable, multi-purpose manipulator[s] programmable in three or more axes, which can be either fixed in place or mobile for use in industrial applications". (IFR Statistical Department, 2017a, p. 25) Service robots are "actuated mechanism[s] programmable in two or more axes with a degree of autonomy, moving within [their] environment, to perform intended tasks". (IFR Statistical Department, 2017b, p.10) In simple terms, industrial robots are overwhelmingly computer controlled arms fitted with sensors to sense and attachments to manipulate the physical world; service robots are mostly vehicle-like machines that can navigate their environment partly or completely on their own.

The domestic Canadian robotics industry focusses on programming and integration of robotic hardware which Canada imports from IFR-affiliated firms located primarily in countries like Japan, Germany, and the United States. The IFR publishes aggregate data on these firms' annual shipments by country, industry and task, but they offer little Canada-specific detail.[2] To fill this gap, Dixon (2020) describes at length how import data collected by the Canadian Border Services Agency (CBSA) can be used to track shipments by IFR-affiliated firms after they cross the Canadian border. The resulting Robots! dataset offers a comprehensive record of Canadian firms' robotic hardware purchases over the last two decades.

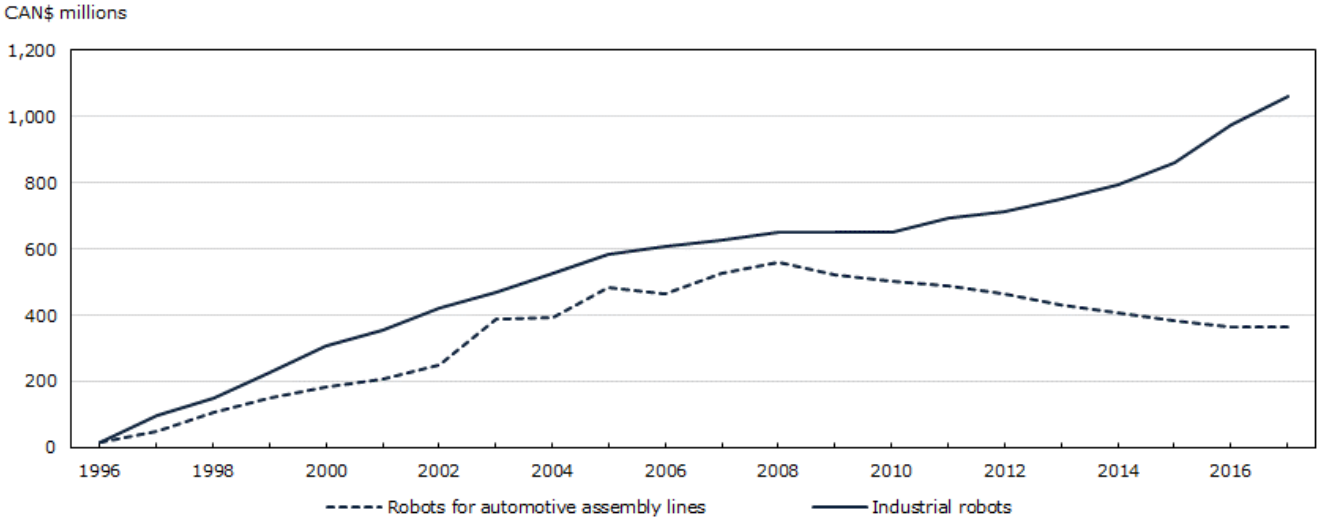
A big advantage of Robots! over other potential sources is that Canada's robot importers are identified by business number. Of the 3,085 businesses importing robot hardware, over half appear to be using them in production. These firms can be found in other Statistics Canada data, and the combined data can be used to gain insights on what type of firms use robots, and how their behaviour changes afterwards.[3] Dixon, Hong and Wu (henceforth DHW, forthcoming) use the National Accounts Longitudinal Microdata File (NALMF) for all firms over the 2000-2016 period and more detailed information available in the Workplace and Employee Survey (WES) for select firms in the years 2001-2006 to explore what robots have been doing in the Canadian economy.

2. The IFR data for Canada only is limited to after the year 2010. The Robotic Industries Association (RIA), North America's IFR member, has data on Canada from year 2005. But the RIA data cover only the shipments from North American-based firms and affiliates, missing shipments from other countries.
3. Robotics wholesalers (located in NAICS 41723, most often the Canadian affiliates of the major global robotics firms) and programmers/integrators (NAICS 5415) represent about 40% of firms. These robot intermediaries may be of research interest, as it is an open question how much they capture of the value robots add, relative to the firms to which they sell. Note that wholesalers may also be involved in programming and integration. About 5% of importers are in industries that are deemed to most likely be non-robot intermediaries, including finance and insurance (NAICS 52), real estate and rental and leasing (NAICS 53) and couriers and messengers (NAICS 492). Unlike their robot intermediary counterparts, these intermediaries are unlikely to add much value to the robots they are importing.

Robots in the Canadian Economy

By matching business numbers from the Robots! and the NALMF data, Dixon (2020) characterizes the firms by industry and geography. Chart 1 shows that the individual sector with the largest stock of robots in Canada over most of the period covered by the data is the automotive sector.[4] The result is unsurprising: the global auto industry is the most enthusiastic investor in robots, and is still the most prominent user worldwide. Canadian robot stocks in the sector grew sharply between 2000 and 2008, but investment dropped precipitously in the wake of the global financial crisis and stocks have been roughly flat since then.

Chart 1
Robot stock, industrial robots and robots for automotive assembly lines



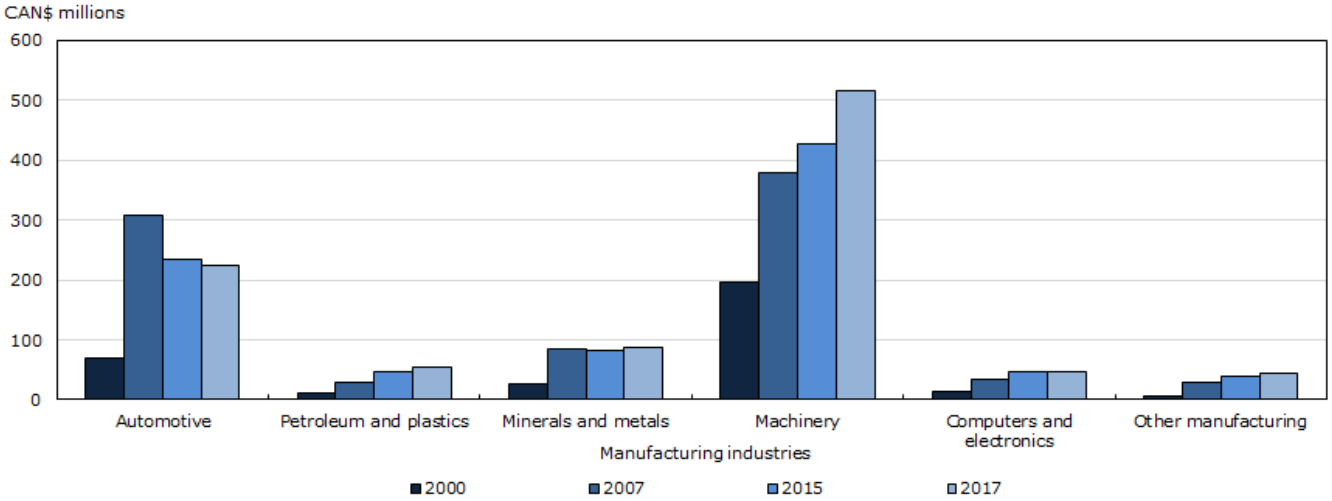
Note: Robot stocks calculated based on 12-year useful life suggested by the International Federation of Robotics.
Source: Statistics Canada, import data.

Chart 2 shows that robot use in other manufacturing industries has expanded especially after 2012, led by machinery manufacturing (NAICS 333), plastics and rubber (NAICS 326), primary and fabricated metal manufacturing (NAICS 331 and 332) electrical/electronics (NAICS 335) industries.

Outside of manufacturing, Chart 3 shows that there has been robotics investment in other goods (including agriculture, mining, utilities and construction) and services. The largest single service sector with robotic investment has been healthcare sector. The exact nature of this automation is unclear, although some of it almost certainly includes laboratory automation (including pipetting robots and laptop robot arms) in medical diagnostics. The robots going into other parts of the healthcare sector are more difficult to characterize, but investment in them seems to be significant.

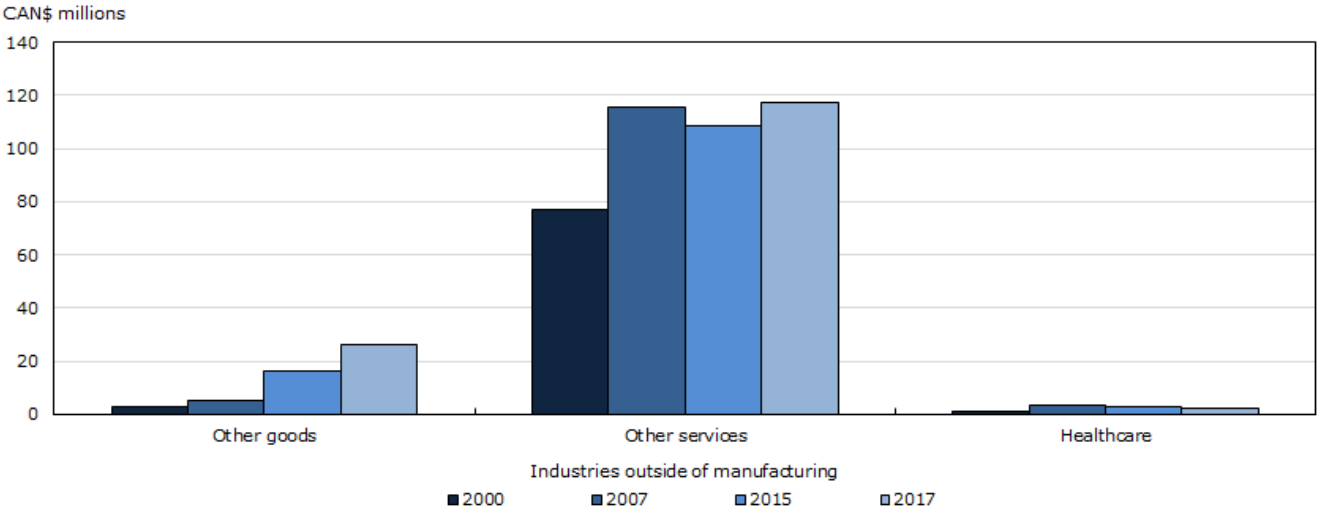
4. This chart relies only on Robots! data, which has a separate category for robots for automotive assembly. Subsequent charts show only firms that can be identified as robot using firms. The automotive sector includes NAICS 326193 (Motor vehicle plastic parts), 32621 (Tire), 3361-3363 (Motor vehicle, body and trailer, and parts manufacturing), 415 (Motor vehicle and motor vehicle parts and accessories merchant wholesalers), and 8111 (Automotive repair and maintenance).

Chart 2
Robot stock by industry, manufacturing industries, selected years



Note: Robot stocks calculated based on 12-year useful life suggested by the International Federation of Robotics.
Sources: Statistics Canada, Import Data and National Accounts Longitudinal Microdata File.

Chart 3
Robot stock by industry, industries outside of manufacturing, selected years

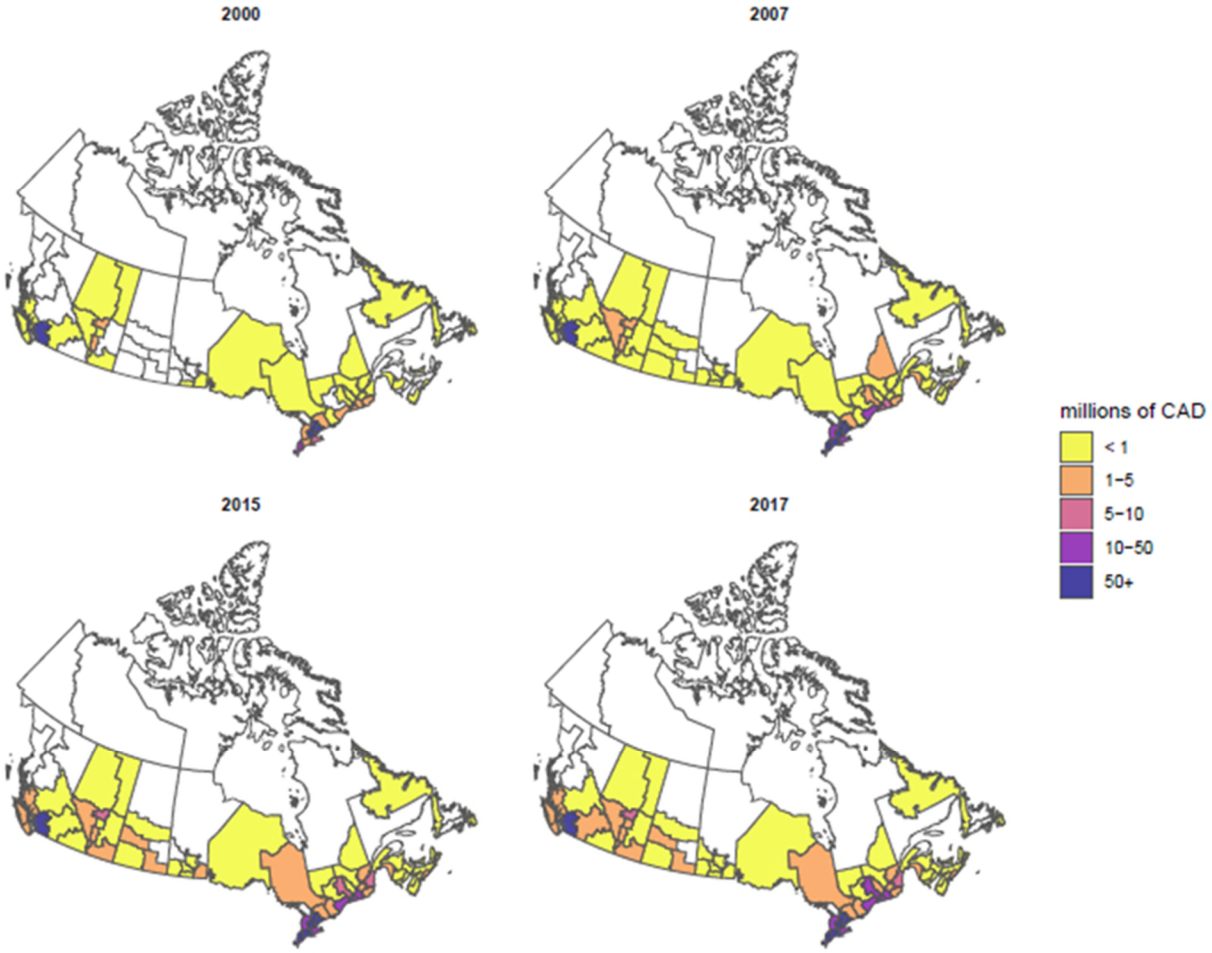


Note: Robot stocks calculated based on 12-year useful life suggested by the International Federation of Robotics.
Sources: Statistics Canada, Import Data and National Accounts Longitudinal Microdata File.

Figure 1 shows the geographical distribution of robots in selected years. The addresses of importing firms, including intermediaries, are used to assign robots to approximate economic regions within Canada. The maps show that robots have been spreading across Canada, with almost all provinces and most intra-provincial regions adopting some industrial robots by 2017. Much of the value is concentrated in Canada's major cities (Vancouver, Toronto and Montreal), and also the industrial areas around Windsor and Hamilton that are home to Canada's automotive sector.[5] Outside of Canada's three largest cites, robots have proliferated especially across the Prairies. Both Alberta and Saskatchewan have experienced relative increases in robot intensity over time.

5. These cities are also entry points for imports destined for other parts of the country, so economic region-level stocks derived from import data may be overstated for them and understated for other regions.

Figure 1
Robot stock by economic region



Note: Robot stocks calculated based on 12-year useful life suggested by the International Federation of Robotics.
Sources: Statistics Canada, import data and National Accounts Longitudinal Microdata File.

Why, Robots!?

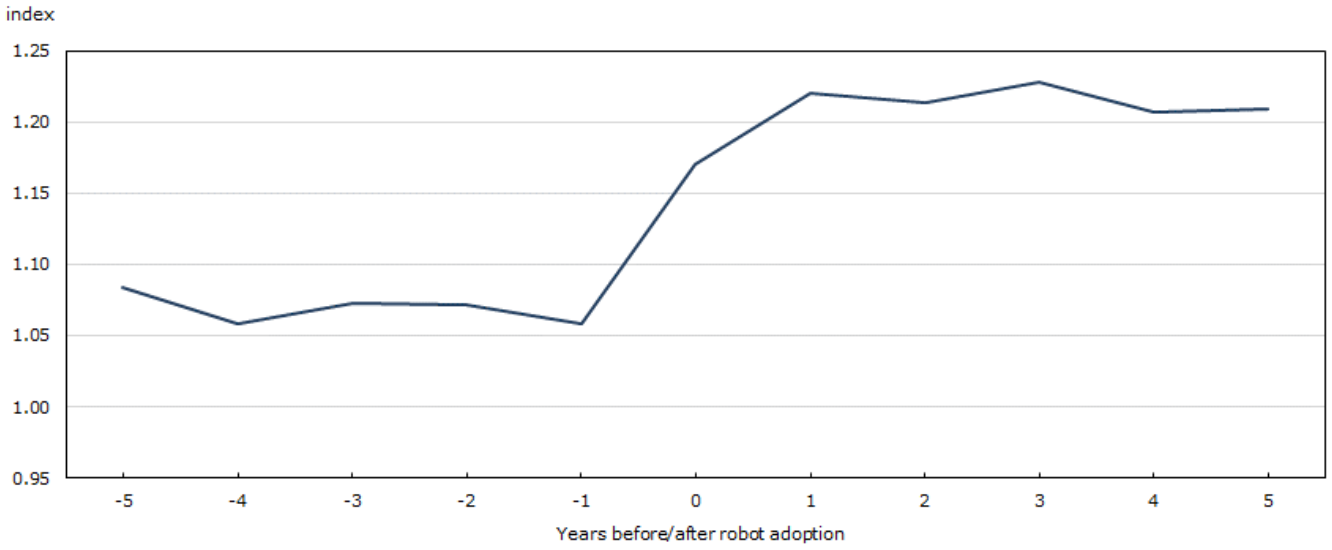
Dixon, Hong and Wu (forthcoming) use Robots! along with NALMF and WES data to explore how firms' robot adoption affects them and the people working for them. It finds that firms that adopt robots experience increases in multi-factor productivity.[6] Using the more detailed information in the Worker Employer Survey (WES), DHW find that these productivity increases are associated with organizational changes within the firm. But these organizational changes do not involve shedding workers overall: Chart 4 shows that they are associated with unconditional increases in employment of almost 20% on average after the robots arrive.

DHW control for various other factors that could influence firms' employment such as investment in other machinery and equipment (M&E) and information and communications technology (ICT), exposure (or lack thereof) to import competition, and previous revenue growth. They also use matching methods

6. There are likely firms among the non-adopters that purchase robots through Canadian intermediaries. This measurement error should bias estimates of productivity improvements downwards.

and instrumental variables to control for unobservable differences between robot and non-robot adopters. Even after controlling for other factors, they find that firms in every robot-using industry increases total employment on average.

Chart 4
Change in employees (indexed to firm's first year in sample)



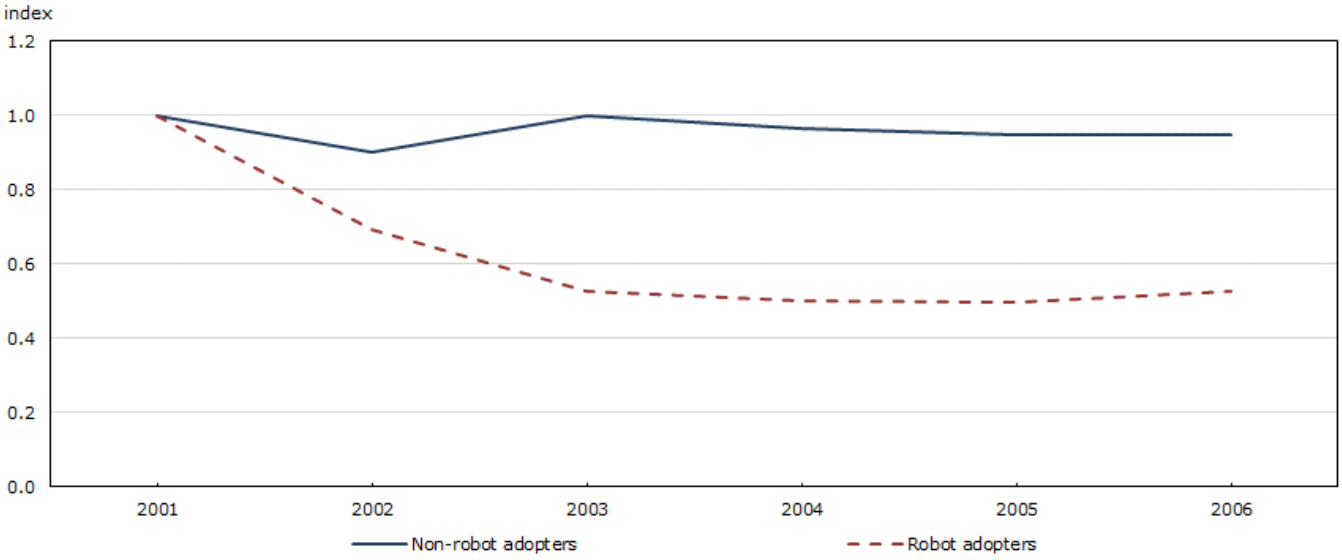
Note: Robot stocks calculated based on 12-year useful life suggested by the International Federation of Robotics.
Sources: Statistics Canada, import data and Workplace and Employee Survey.

Although employment increases overall, robots do cause turnover within firms for all types of workers, and the composition of the workforce changes. DHW find from the WES that surveyed firms over the 2001-2006 period were more likely to reduce employment among middle skilled workers, while increasing both high and low skilled employment. While some of the tasks robots commonly perform, such as placing, packaging and palletizing, have commonly been performed by low-skilled manual labour, many of them involve a degree of skill. For example, operating machine tools or preparing laboratory samples for testing have involved operators or lab technicians with vocational training, and robots may be displacing them.

The most negatively affected workers, however, appear to be managers. The turnover at the management level increases, but as Chart 5 shows, fewer managers are promoted or hired to replace the ones that leave.[7] DHW find that after controlling for observable and unobservable factors, both the number and fraction of employees that are managers fall when robots are adopted.

7. DHW also find that firms adopting robots have a greater tendency to hire managers from outside the firm, as opposed to promoting from within, than non-adopting firms.

Chart 5
Number of managers (indexed to 2001)



Note: Robot stocks calculated based on 12-year useful life suggested by the International Federation of Robotics.
Sources: Statistics Canada, import data and Workplace and Employee Survey.

The decline in the number of managers are associated with an increase in the span of control, a reallocation of decision rights, and a change of incentives within the firm. Individual managers report supervising more people after robot adoption, and firms report a reduction in the number of layers between headquarters and the shop floor. Some typical managerial responsibilities, such as worker training are moved closer to the factory floor, while others, like choice of production technologies are moved to business owners or to the corporate head office. Finally, compensation systems appear to make greater use of individual incentive pay after robots arrive.

DHW suggest two possible reasons for why firms change the way they are organized upon adopting robots. One possibility is that robots, in addition to operating with consistent precision, allow for more precise measurement of outcomes. Firms that invest in robots are more likely to report that product quality is a strategic priority, and that measuring performance is an important priority. Because monitoring quality and performance are common managers' tasks, firms need fewer of them once the robots arrive. The greater use of individual incentives goes hand in hand with an increasing ability to attribute outcomes like quality to individual performance.

Another possibility is that robots allow firms to be more flexible. One of the main advantages of robots compared to other machines is that they can be reconfigured for new varieties or different tasks quickly and inexpensively. Firms that use nimbleness as a market strategy also need workers who are able to switch easily between tasks. In addition to being given more decision-making authority, workers at firms with robots report that their schedules become less predictable. These results are consistent with firms needing workers capable of performing a greater variety of less routine tasks.

Conclusion

Recent improvements in robotics have rekindled ancient fears about the impact of robotics on humankind. Unfortunately, existing data seldom distinguishes robots from other types of automation, so research into their impact so far has been difficult. This article introduces research from a new Statistics Canada dataset, Robots!, on the impact of robots at the firm-level.

The research suggests that some of the worst fears, like a robocalypse for labour, are not evident in the data. Firms hire more, not fewer, workers after investing in robots. However, they do appear to need different types of workers. The workers they hire tend to have either higher or lower skills than the ones that leave the firm. The workers are given greater decision-making authority and greater individual incentives, but their work with or alongside robots becomes less routine.

Managers, on the other hand, appear not to fare as well when robots arrive. Robot-adopting firms use fewer layers of management, more managers leave and fewer of them are hired. The changes in firm organization could be associated with features of robots that allow for more precise measurement, and also more flexibility on the part of the firm.

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