Catalogue no. 36-28-0001
ISSN 2563-8955

Economic and Social Reports

Understanding Canada's innovation paradox: Exploring linkages between innovation, technology adoption and productivity

by Guy Gellatly and Wulong Gu

Release date: July 24, 2024

Statistics Canada Statistique Canada

Canada

How to obtain more information

For information about this product or the wide range of services and data available from Statistics Canada, visit our website, www.statcan.gc.ca.

You can also contact us by

Email at infostats@statcan.gc.ca

Telephone, from Monday to Friday, 8:30 a.m. to 4:30 p.m., at the following numbers:

- Statistical Information Service 1-800-263-1136
- National telecommunications device for the hearing impaired 1-800-363-7629
- Fax line 1-514-283-9350

Standards of service to the public

Statistics Canada is committed to serving its clients in a prompt, reliable and courteous manner. To this end, Statistics Canada has developed standards of service that its employees observe. To obtain a copy of these service standards, please contact Statistics Canada toll-free at 1-800-263-1136. The service standards are also published on www.statcan.gc.ca under "Contact us" > "Standards of service to the public."

Note of appreciation

Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued co-operation and goodwill.

Understanding Canada's innovation paradox: Exploring linkages between innovation, technology adoption and productivity

by Guy Gellatly and Wulong Gu

DOI: https://doi.org/10.25318/36280001202400700002-eng

This Spotlight is a complement to a new presentation Research to Insights: Challenges and Opportunities in Innovation, Technology Adoption and Productivity, highlighting key findings from the agency's productivity research program and recent business surveys. It also explores the relationship between competitive intensity and innovation and informs on the pace at which disruptive technologies, such as artificial intelligence, are being integrated into the economy.

Increases in labour productivity are integral to long run improvements in living standards. Since the early 1980s, growth in labour productivity has accounted for over 90% of the growth in Canada's real gross domestic product (GDP) per capita while the remainder has come from growth in labour utilisation. While declines in per capita output since mid-2022 have reflected near-record population increases, labour productivity has also trended lower, decreasing in six of the past eight quarters. Business labour productivity in early 2024 was below levels observed just before the COVID-19 pandemic.

Improvements in labour productivity can come from three sources: 1) **capital deepening**, which entails making more investment goods available to workers, 2) **improvements in labour composition**, which can come from skill upgrading led by increases in experience and educational attainment, and 3) **growth in multifactor productivity** (MFP), which are improvements in business efficiency that are often attributed to innovation and technological change, organizational change, and scale economies. Multifactor productivity measures the efficiency with which inputs are being used in the production process and the ratio of real gross domestic product (GDP) to combined labour and capital inputs.[1]

Statistics Canada's recent estimates of multifactor productivity for reference year 2022 provide new insight into the relative contributions of the above factors. They suggest that innovation and advanced technology use have not translated into sustained improvements in labour productivity beyond their measured impacts on capital and labour. This result aligns with what is often termed the **innovation paradox**: Despite substantial investments in innovation and technological capacity, the payoffs from innovative activity, insofar as they pertain to the productivity- and output-enhancing benefits that arise from the commercialization of new knowledge, have been comparatively modest.[2]

1. For background on productivity concepts and measurement, see Baldwin et al. (2014).
2. For a detailed overview of Canada's innovation performance, see the Conference Board of Canada's 2024 Innovation Report Card.

Lower capital investment weighs on labour productivity growth

While slower labour productivity growth over much of the past decade stems largely from declines in business investment, concerns persist over the extent to which businesses are harnessing the benefits of innovation and advanced technologies. Slower labour productivity growth since 2015 has been largely due to weak capital investment, which was pervasive across industries. Investment per worker in 2022 was nearly 20% below levels in 2014, reflecting in part the sizable pull back in non-residential capital spending after the oil price shock in the mid-2010s. In early 2024, real investment in non-residential structures was 25% below peak levels, while real outlays on machinery and equipment were 17% below.

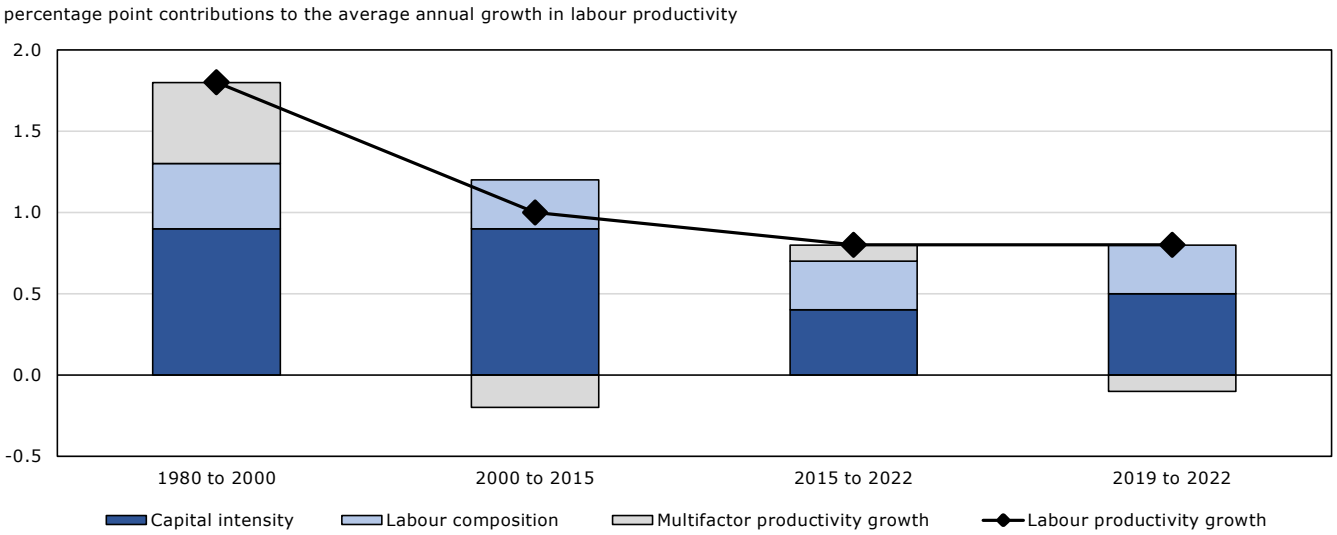
Little boost to productivity from technological innovation

Over the past two decades, increases in multifactor productivity—which are improvements in business efficiency that stem from innovation and technology use, organizational change, and scale economies—have not translated into sustained improvements in labour productivity. Chart 1 reports on the relative contributions of different factors to labour productivity growth over selected periods. Multifactor productivity, on average, contributed negatively to labour productivity growth from 2000 to 2015 followed by small positive contributions from 2015 to 2022 as the gains from capital intensity slowed. The contribution of multifactor productivity to labour productivity growth in the latter period was tempered by volatility during the pandemic years. From 2019 to 2022, multifactor productivity declined on average by 0.1% annually.[3]

It should be stressed that the trend towards weaker multifactor productivity growth is not unique to Canada and has been observed, in varying degrees, in most advanced economies including the United Kingdom, and the United States. The potential causes of slower multifactor productivity growth are summarized in the International Monetary Fund's 2024 World Economic Outlook and include, among other factors, the misallocation of capital and labour away from higher productivity firms, the waning benefits associated with earlier investments in information and communications technologies, and declines in business dynamism. While the dynamics of multifactor productivity growth are complex, Canada' recent track record aligns with the view that businesses need to more fully exploit the benefits of innovation and advanced technology to expand output and raise productivity.

3. Overall estimates of multifactor productivity growth were flat for the combined 2000 to 2019 period.

Chart 1
Contributions to labour productivity growth, selected periods



Notes: Data on labour productivity growth are the average annual compound growth rates for the specified period. Data on capital intensity, labour composition and multifactor productivity are contributions to the annual average growth rate. Data may not add up due to rounding.
Source: Statistics Canada, table 36-10-0208-01.

Competition as a driver of investment and innovation

A 2023 report by the Competition Bureau of Canada found that there has been an overall decline in competitive intensity in recent decades, noting the potentially negative implications for innovation and productivity growth. This aligns with research at Statistics Canada, which points to weaker investment as business entry rates trended lower (Gu, 2024).

Recent data from innovation and technology surveys underscore the positive linkages between competition, innovation, and business efficiency. Businesses that face more competitors are substantially more likely to introduce innovations than those with fewer competitors (Survey of Innovation and Business Strategy, 2022). In responding to changes in competition in their main market, over one-third of businesses (38%) introduced or accelerated the introduction of new goods or services, while over half (55%) responded by introducing new technology or new processes. Advanced technology use is also correlated with innovation activity. More than four in five businesses that used advanced technology reported introducing innovations, compared with three in five businesses that did not use advanced technology. Many companies, in turn, reported that innovation and technology have productivity-enhancing effects. In the second quarter of 2024, almost three in ten businesses (28.3%) reported that technology adoption and innovation improved their ability to operate efficiently over the previous twelve months (Canadian Survey on Business Conditions).

Challenges and opportunities around R&D and patent activity

While business expenditures on research and development (R&D) have risen, as have the receipts that R&D-performing firms earn from intellectual property, concerns over the intensity with which businesses are investing and capitalizing on their investments in knowledge capital persist, especially in relation to many competitor economies. Canada's overall R&D intensity remains well below many other countries, and in 2021, fell two spots to 19th in the Organisation for Economic Co-operation and Development

(OECD). At the same time, business sector R&D spending as a share of GDP was the second lowest in the G7.

R&D-performing businesses in Canada generated $8.9 billion from their intellectual property in 2021, up over one third from 2020, with much of the growth coming from higher receipts from software. Software sales accounted for almost three quarters of the total receipts from intellectual property. While over one in five businesses owned an intellectual property asset in 2022, only 5.8% owned patents (Survey of Innovation and Business Strategy).

Trends in Canadian patent applications were recently examined by Abbes, Lafrance-Cooke and Leung (2023). The authors showed that the growth in patent applications in Canada and applications abroad by Canadians stagnated in the years leading up to the pandemic, falling to levels observed in the early 2000s. New research by Gagnon and Ma (2024) examined the advanced technologies associated with patent applications, focusing on trends among Canadian and foreign-owned multinationals. Applications for high-tech patents, largely for communications, computer, and automated business equipment, accounted for about one third of all applications by Canadian-resident businesses between 2001 and 2019. Their study also showed that Canadian multinationals exhibited superior intellectual property generation than foreign-owned multinationals, with Canadian-controlled businesses generating more intellectual property relative to their investments in R&D.

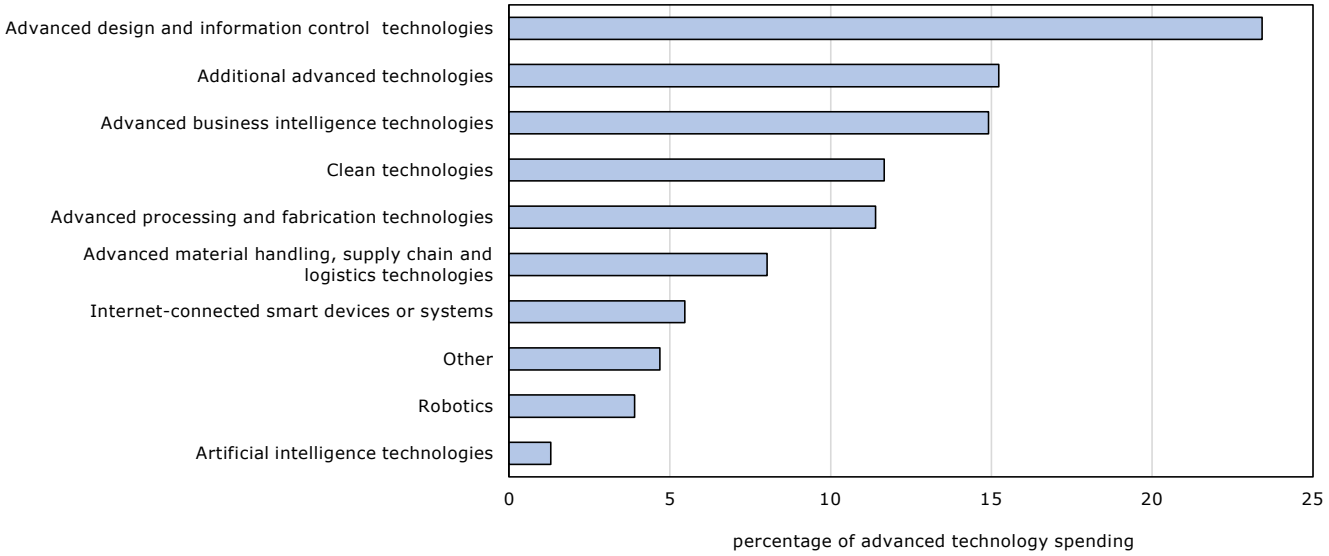
Comparatively low capital spending on advanced technologies

Advances in artificial intelligence (AI) technologies are widely touted as game-changers, potentially reshaping business processes and fostering innovation-led increases in productivity.[4] The adoption of AI and other disruptive technologies is still in its early stages. The 2022 Survey of Advanced Technology found that only 3.1% of businesses reported using artificial intelligence, while 2.1% reported using robotics. By early 2024, 6.1% of businesses reported using AI for producing goods or delivering services during the previous 12 months (Canadian Survey on Business Conditions, second quarter 2024).[5]

To reap the benefits of major technological advances, adoption rates and expenditure levels on disruptive technologies could continue to accelerate in coming years. However, data from the 2022 Survey of Advanced Technology showed that overall capital spending on advanced technologies, defined more broadly across a range of technology types, has been modest. While almost two thirds of businesses adopted at least one type of technology, total capital outlays on all advanced technologies from 2020 to 2022 totalled just $6 billion, with disruptive technologies such as artificial intelligence and robotics accounting for only a small share of this spending (Chart 2).[6]

4. For an analysis of the potential productivity impacts of AI, see Billy-Ochieng' et al. (2024).
5. Using data from the Survey of Digital Technology and Internet Use, Lockhart (2023) found that 3.1% of Canadian enterprises in 2021 had adopted AI, but that the adoption rate rose to one in five among businesses with more than 100 employees.
6. By comparison, business sector spending on R&D from 2020 to 2022 totaled $79.2 billion, while private sector outlays on machinery and equipment amounted to $241 billion.

Chart 2
Share of capital expenditures on advanced technology by type of technology, 2020 to 2022



Source: Survey of Advanced Technology. Statistics Canada, table 27-10-0394-01.

Impacts of AI on the workforce are expected to be far-reaching

Growing our body of research on the changing nature of work will continue to be critical, as the shift towards cognitive, non-routine work has accelerated since the pandemic (Frenette 2023). Previous work on the impact of robot investment on firm performance has shown that investments in such emerging technologies not only raise firms' productivity, but also lead to firms hiring more, rather than fewer workers, while evolving the skills required (Dixon 2020). Building on these findings, forthcoming research at Statistics Canada will provide experimental estimates of potential AI occupational exposure and complementarity—identifying occupations where AI will complement human labour and potentially create new tasks/jobs, as opposed to automate the majority of tasks. Mehdi and Morissette (2024, forthcoming) find that 40% of workers have low exposure to AI, while the remaining 60% divide evenly into two groups: workers with high exposure to AI that have high complementarity with these technologies (29%) and workers with high AI exposure with low complementarity (31%). High earners are more likely than middle-earners to be in high AI exposure jobs with high complementarity.

Essentially, Canadian businesses are innovating, but there is little evidence that innovations have translated into productivity growth or higher standards of living. Compared to OECD economies, we are lagging in commercialization and research and development intensity. And yet, there are major opportunities on the horizon with the adoption of AI and emerging technologies, which have the potential to reshape how companies do business and create new jobs or tasks. Continuing to monitor these developments closely will be a priority for the agency, to provide information on their transformative nature and potential implications for Canada's workforce and productivity growth.

Authors

Guy Gellatly is with the Strategic Analysis, Publications and Training Division, Analytical Studies and Modelling Branch at Statistics Canada. Wulong Gu is with the Economic Analysis Division, Analytical Studies and Modelling Branch at Statistics Canada.

References

Abbes, C., A. Lafrance-Cooke, and D. Leung. 2023. *Patenting Activity of Woman-owned Businesses in Canada*. Economic and Social Reports. Catalogue no. 36-28-0001. Ottawa: Statistics Canada.

Billy-Ochieng', R., A. Arif, and D. Garcia. 2024. *Artificial Intelligence Technologies can help address Canada's productivity slump*. TD Economics, May 28, 2024.

Competition Bureau. 2023. *Competition in Canada from 2000 to 2020: An Economy at a Crossroads*. Innovation, Science and Economic Development Canada. Cat. No. Iu54-125/2023E-PDF. Ottawa: Innovation, Science and Economic Development Canada.

Conference Board of Canada. 2024. *2024 Innovation Report Card: Benchmarking Canada's Innovation Performance*. Conference Board of Canada Impact paper, April 11, 2024.

Dixon, J. 2020. *The Effect of Robots on Firm Performance and Employment.* Economic Insights. Catalogue 11-626-X, no. 126. Ottawa: Statistics Canada.

Frenette, M. 2023. *The changing nature of work since the onset of the COVID-19 pandemic.* Economic and Social Reports. Catalogue 36-28-0001, Vol. 3, no. 7. Ottawa: Statistics Canada.

Gagnon, D. and S. Ma. 2024. *Innovation in Focus: Exploring trends in the development of advanced technology through patent applications*. Digital Insights. Catalogue no. 22-02-0001. Ottawa: Statistics Canada.

Gu, W. 2024. *Investment Slowdown in Canada after the mid-2000s: The Role of Competition and Intangibles*. Analytical Studies Branch Research Paper Series. Catalogue 11F0019M, no. 474. Ottawa: Statistics Canada.

Lockhart, A. 2023. *Automation Nation? AI Adoption in Canadian Businesses*. The Dais, Toronto Metropolitan University. September 2023.

Mehdi, T. and R. Morissette. *Experimental Estimates of Potential AI Occupational Exposure in Canada*. Analytical Studies Branch Research Paper Series, Catalogue 11F0019M. Ottawa: Statistics Canada, forthcoming.