Research to Insights: Challenges and Opportunities in Innovation, Technology Adoption and Productivity

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About *Research to Insights*

The *Research to Insights* series of presentations features a broad range of findings on selected research topics. Each presentation draws from and integrates evidence from various studies that use innovative and high-quality data and methods to better understand relevant and complex policy issues.

Based on applied research of valuable data, the series is intended to provide decision makers, and Canadians more broadly, a comprehensive and horizontal view of the current economic, social and health issues we face in a changing world.

Context

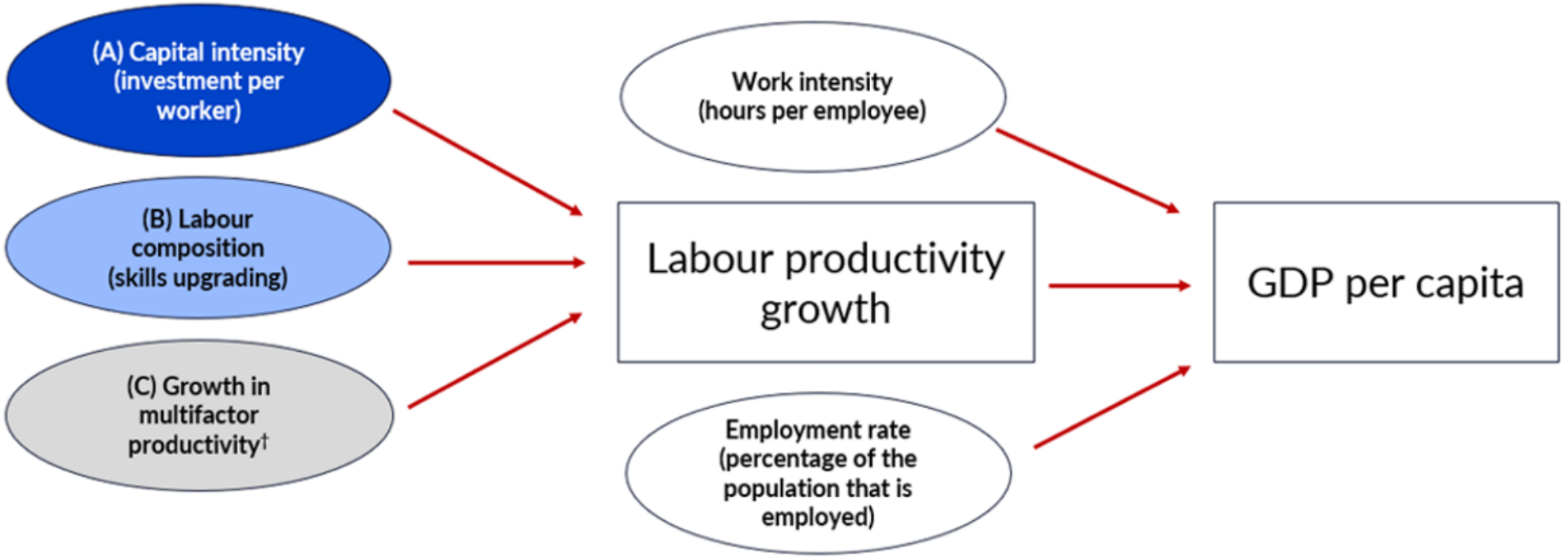
- Increases in labour productivity are closely associated with long-run improvements in living standards. Since the early 1980s, over 90% of the increase in Canada's real gross domestic product per capita has reflected improvements in labour productivity. While slower labour productivity growth over 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.

- Statistics Canada's recent estimates of multifactor productivity 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 is consistent with the "innovation paradox." While many businesses report developing new products and processes, the payoffs from innovative activity, insofar as they pertain to the aggregate economic returns from the commercialization of new knowledge, have been comparatively modest.

- This presentation highlights data and analysis at Statistics Canada that can be used to explore linkages between innovation, technology adoption and productivity. It draws on new estimates from the agency's productivity research program, along with recent surveys that examine the innovation and technological stance of Canadian businesses. The presentation is intended to support ongoing research on the competitiveness of Canada's economy.

Figure 1
Framework: Innovation, productivity growth and living standards



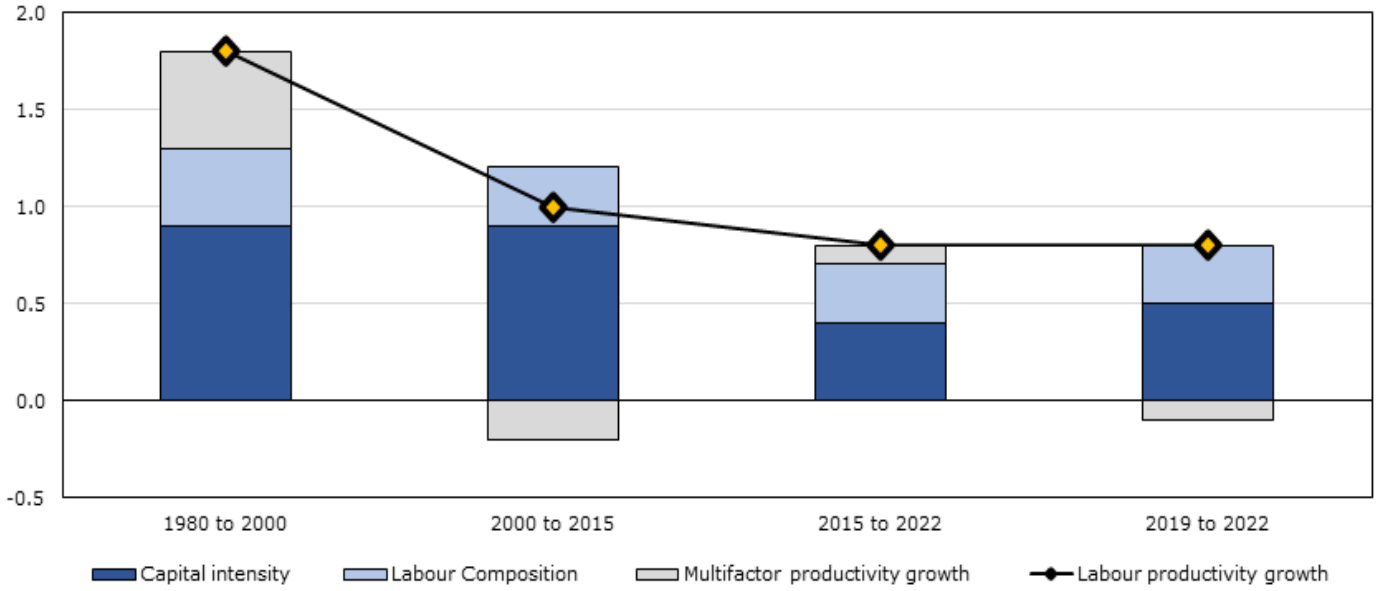
† The residual portion of labour productivity growth that is not attributable to gains in capital intensity (A) and skills upgrading (B) is called growth in multi-factor productivity (C). It measures the efficiency with which inputs are used in production. Growth in multi-factor productivity is often associated with innovation and technological progress.

Note: GDP = Gross domestic product
Source: W. Wang (2021) and Baldwin et al. (2014).

Less productivity growth from capital investment coupled with low contributions from multifactor productivity, which partly reflect modest returns from innovation and technology

Chart 1
Contributions to labour productivity growth, selected periods

percentage point contributions to the average annual growth in labour productivity



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.

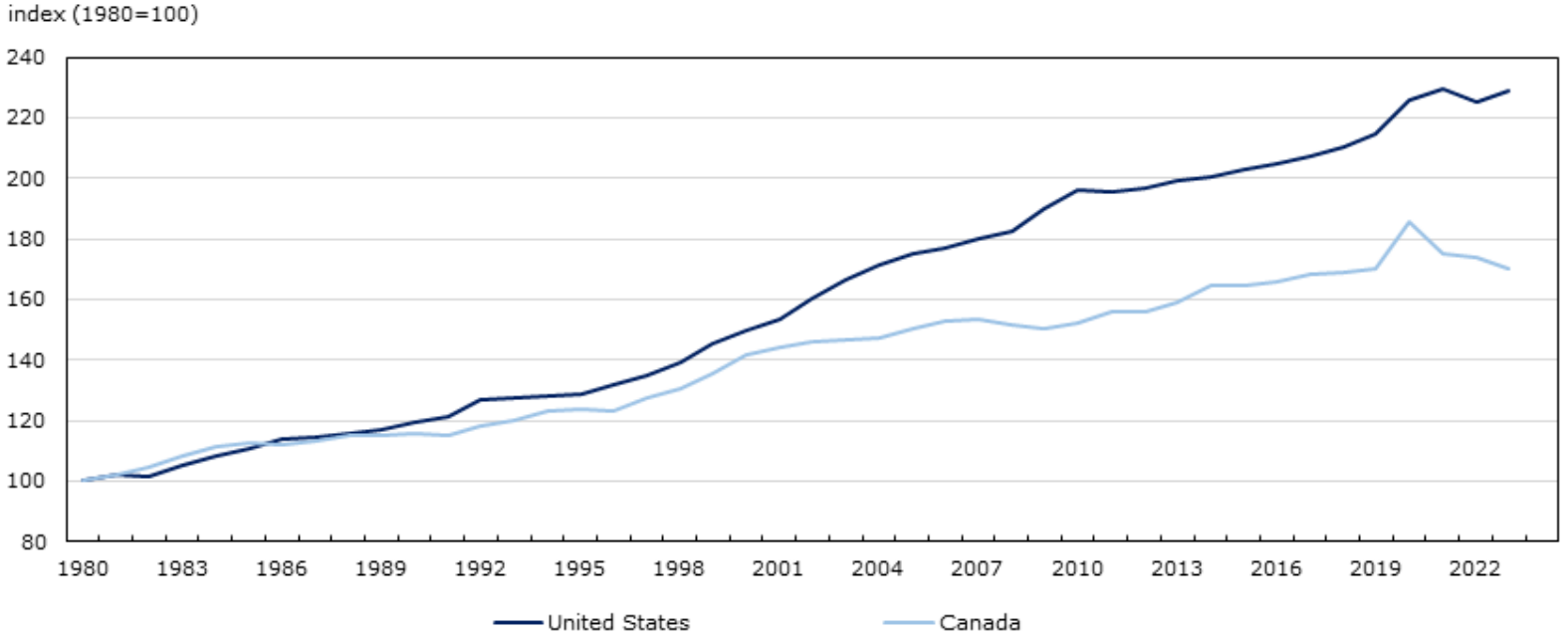
- Non-residential business investment scaled back sharply after the oil price shock in the mid-2010s. Real capital outlays in early 2024 were 22% below peak levels a decade earlier.
- Slower labour productivity growth since 2015 has been largely attributable to weak capital investment, which was pervasive across industries. Investment per worker in 2022 was nearly 20% below 2014 levels.
    - Large and medium-sized firms have accounted for nearly the entire decrease in investment per worker. Declines in capital intensity were more pronounced among foreign-controlled firms.

For more information: *The Daily*—Multifactor productivity growth estimates and industry productivity database, 2022

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.

Gap in labour productivity growth between Canada and the United States reflects lower productivity north of the border in several high-tech sectors

Chart 2
Labour productivty growth, Canada and the United States



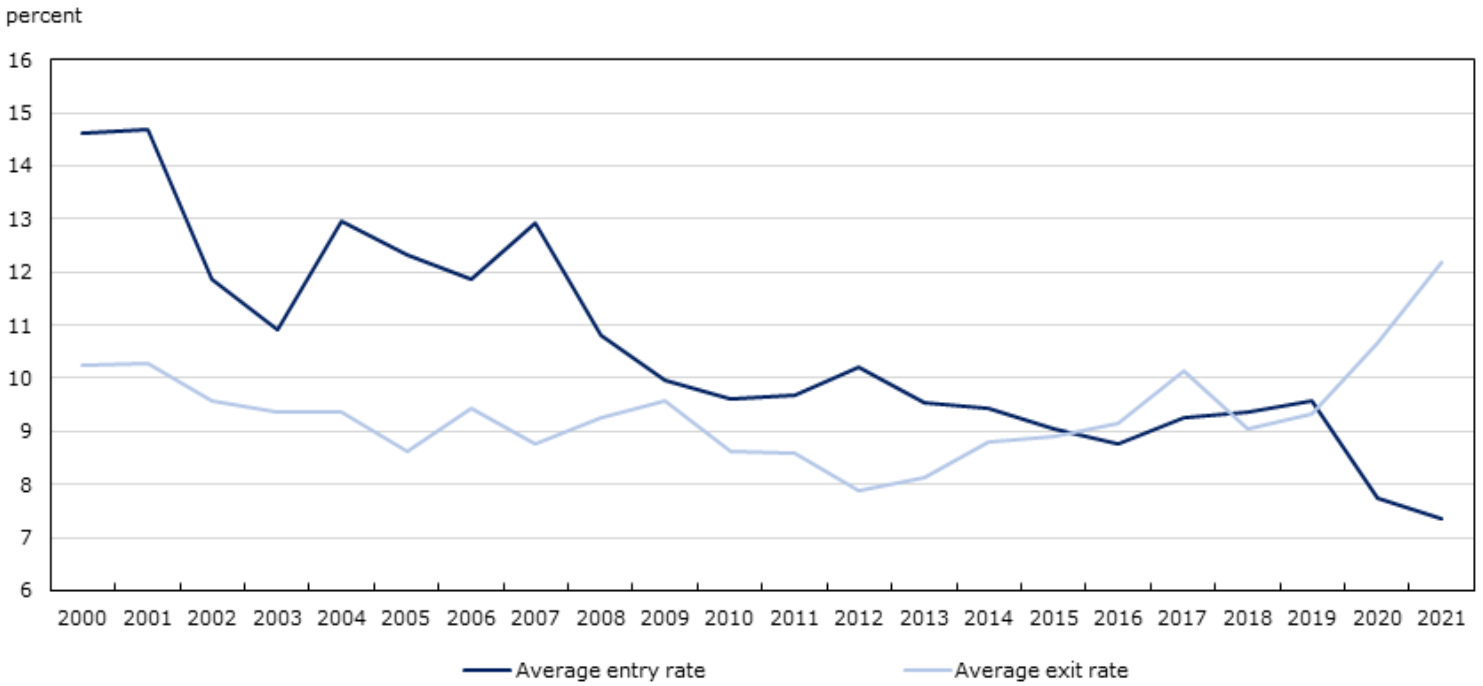
Sources: Statistics Canada and U.S. Bureau of Labour Statistics.

- Since 2000, labour productivity in Canada has increased at an average annual rate of 0.8%, less than half the average annual pace (1.9%) observed in the United States.
- From 2001 to 2019, the information and cultural services industry, which includes telecommunications, was the largest contributor to widening the labour productivity growth gap between Canada and the United States.
- Lower productivity in Canadian computer and electronic product manufacturing also contributed to widening the gap, while higher productivity in Canadian financial services tempered the productivity divergence between the two countries.
- Business demography matters—ongoing research on the productivity gap between Canada and the United States shows that Canada has a larger share of small and medium-sized enterprises (SMEs) than the United States, but that SMEs in Canada are less productive.

For more information: The post-2001 productivity growth divergence between Canada and the United States: The role of the information and cultural services industry.

Opportunities to improve productivity through investment and innovation

Chart 3
Average entry and exit rates in Canadian industries, 2000 to 2021



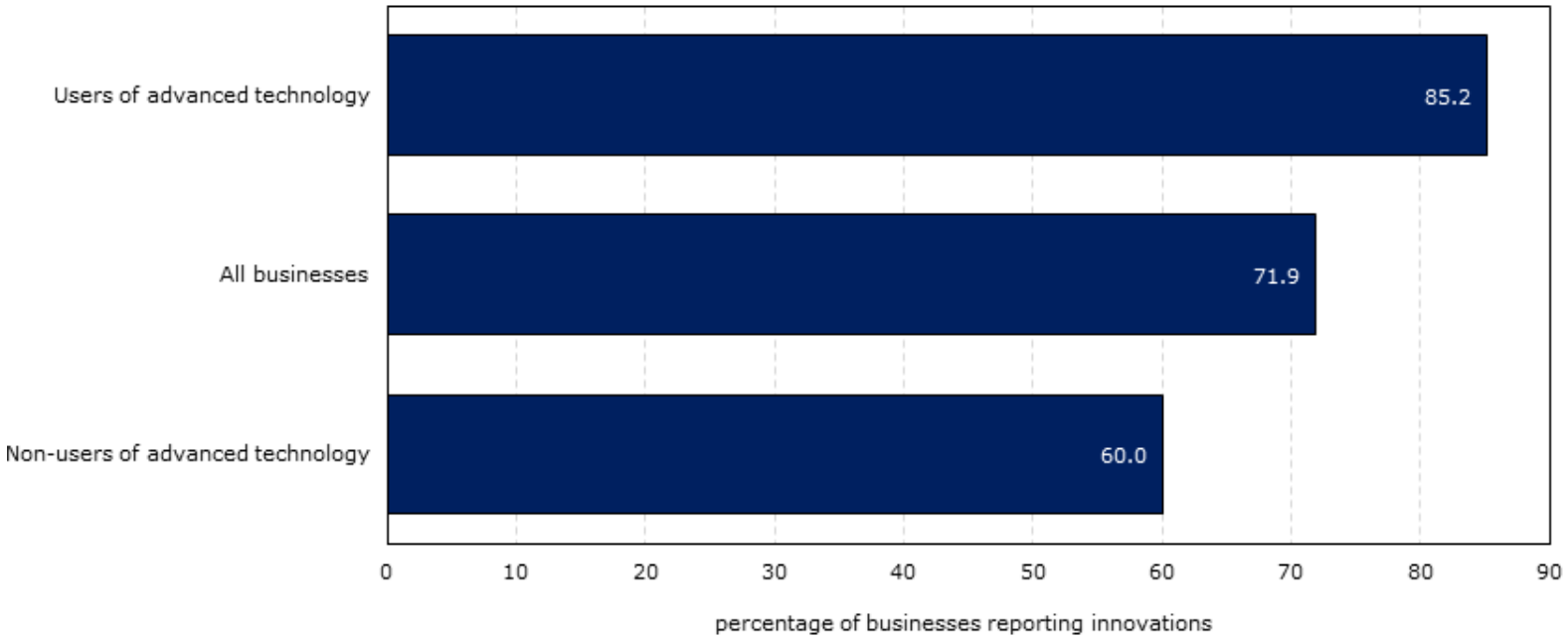
Sources: Gu, forth coming and The National Accounts Longitudinal Microdata File of Statistics Canada.

- Less competition allows dominant firms to gain market power and set higher prices without the threat of being undercut by competitors, leading to higher prices for consumers and businesses
- Less competition may be contributing to weaker investment while hampering innovation.
  - Business entry rates have trended lower, while market concentration has increased since 2015. The Competition Bureau recently found that overall competitive intensity has declined over the past two decades.
  - Businesses that face more competitors are more likely to introduce innovations than those with fewer competitors (Survey of Innovation and Business Strategy, 2022).
- Higher regulation weighs on growth—Transport Canada and KPMG, with contributions from Statistics Canada, have developed a measure of regulatory requirements at the federal level.
  - The number of regulatory requirements rose by 40% from 2006 to 2021.
  - Rising regulatory requirements were found to have a negative effect on output and productivity growth.

For more information: Competition Bureau report finds Canada's competitive intensity in decline and *The Daily*—Survey of Innovation and Business Strategy, 2022.

Businesses invest in innovation and technology adoption—especially in response to competition

Chart 4
Innovation rates, 2020 to 2022



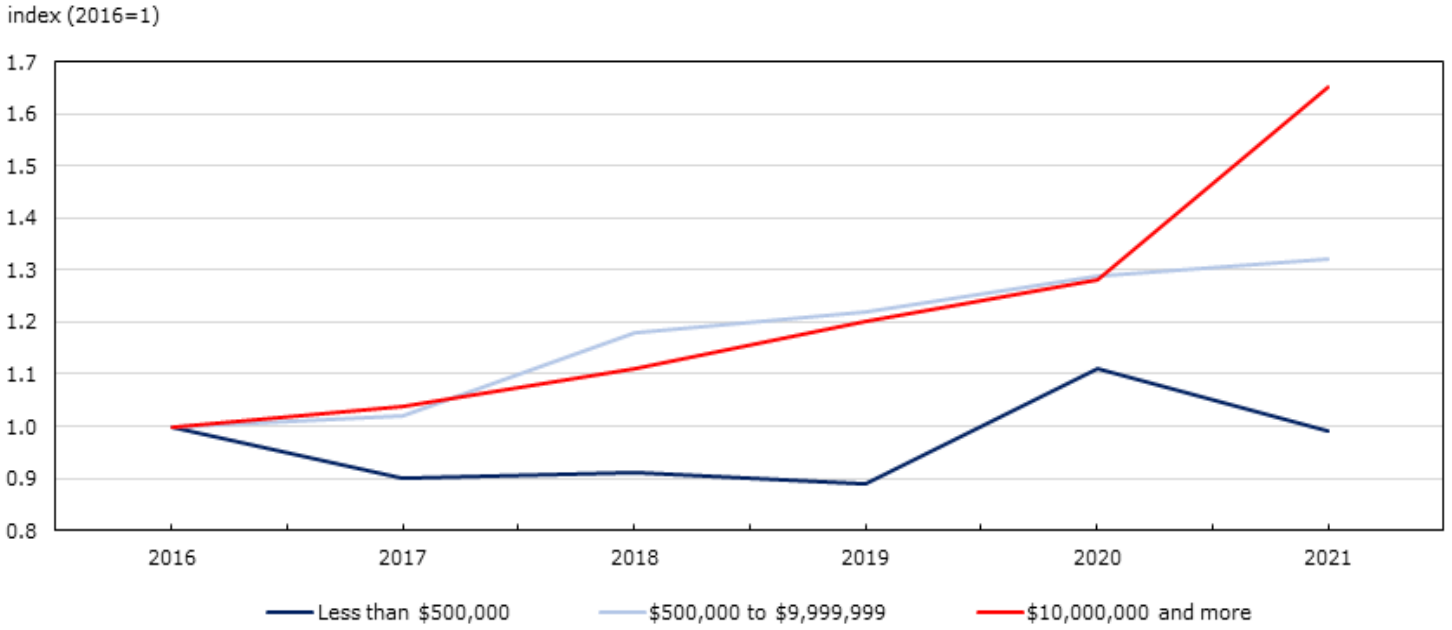
Source: Statistics Canada, Survey of Innovation and Business Strategy, 2022.

- More than four in five businesses that used advanced technology reported innovations, compared with three in five businesses that did not use advanced technology (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. Over one-half (55%) responded by introducing new technology or new processes.
- Nearly two in five businesses that developed and introduced product innovations registered to protect their intellectual property.
- In the second quarter of 2024, almost 3 in 10 businesses (28.3%) reported that technology adoption and innovation improved their ability to operate efficiently over the previous 12 months.

For more information: *The Daily*—Survey of Innovation and Business Strategy, 2022 and Aspects that improved the ability of business or organization to operate efficiently over the last 12 months, second quarter of 2024.

Business research and development spending is ramping up, but overall R&D intensity remains well below that of other major industrial economies

Chart 5
Growth in business research and development spending, by expenditure groups



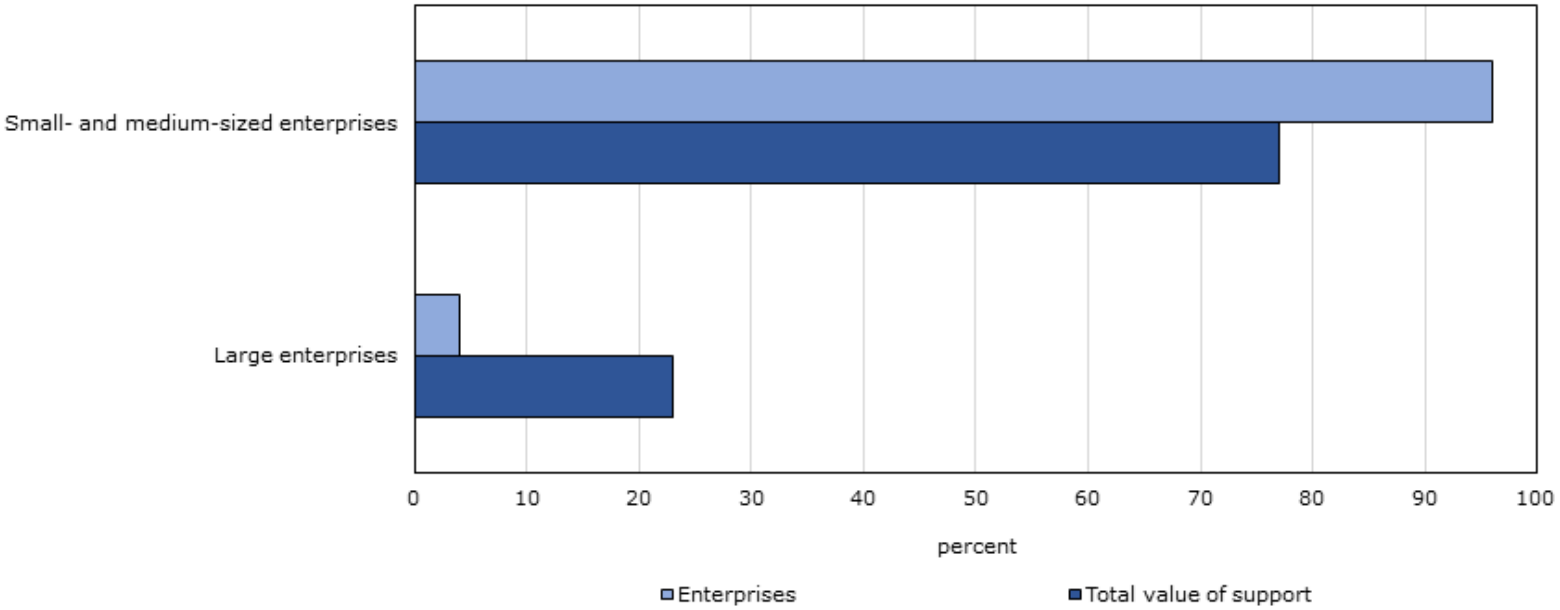
Source: Statistics Canada, table 27-10-0336-01.

- In 2021, most of the growth in industrial R&D spending reflected higher outlays by the largest R&D performers, both domestic and foreign-owned. Early data for 2022 and 2023 point to steady increases in business R&D spending.
- Canada's R&D spending as a share of gross domestic product (GDP) lags well behind the G7 average and, in 2021, fell two spots to 19th in the Organisation for Economic Co-operation and Development. Canada's business-sector R&D spending as a share of GDP was the second lowest in the G7.
- R&D intensities for domestic and foreign-owned producers vary across industries.
    - The average R&D-to-sales ratio for Canadian-owned manufacturers was 2.2% in 2021, compared with 1.6% for foreign-controlled manufacturers.
    - Canadian-owned information and communications technology (ICT) businesses had an average R&D-to-sales ratio of 5.9%, well below the average for foreign-controlled ICT firms (12.9%).
- Foreign multinationals accounted for over 40% of all intramural research and development (R&D) spending by corporations in 2021, and one-third of all corporate expenditures on intellectual property (IP) in 2022.

For more information: *The Daily*—Industrial research and development, 2021 (actual), 2022 (preliminary) and 2023 (intentions) and Activities of multinational enterprises in Canada, Canadian and foreign multinationals, as a share of the Canadian economy.

Many businesses benefited from federal support for innovation and growth during the recovery from the COVID-19 pandemic

Chart 6
Business innovation and growth support by employment size, 2021



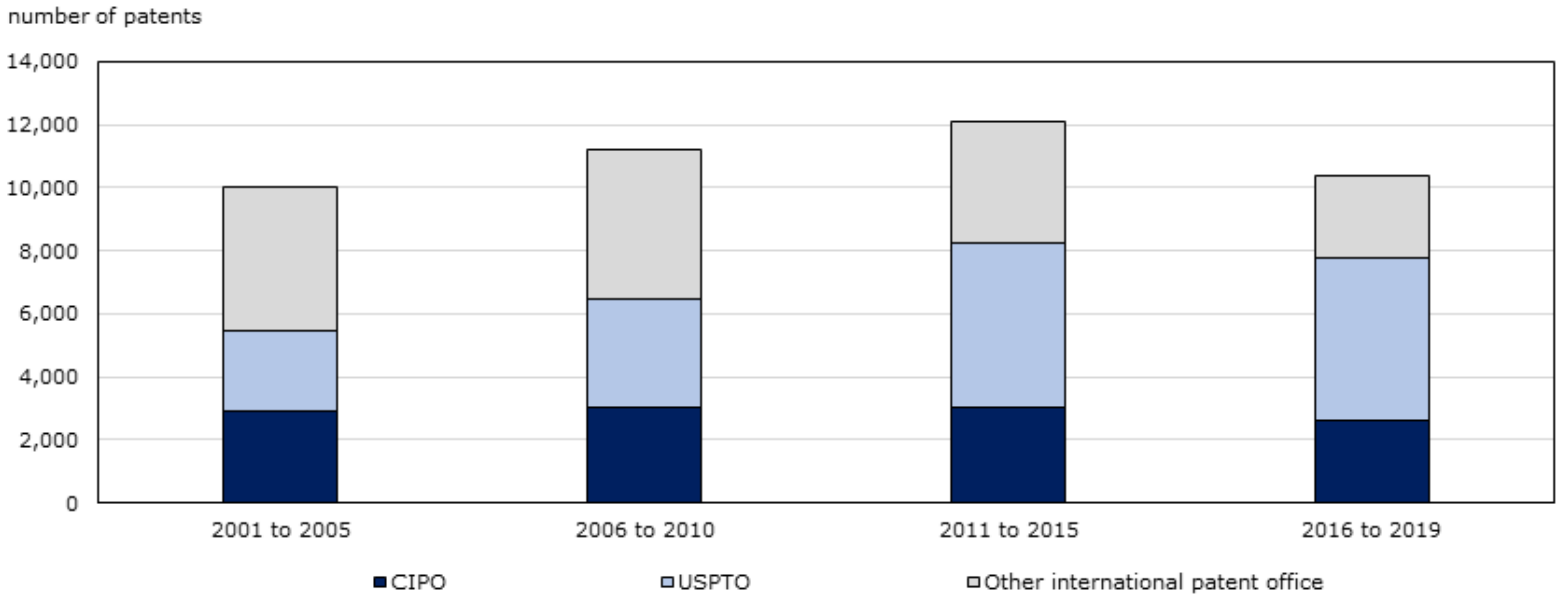
Source: Statistics Canada, table 33-10-0219-01.

- In 2021, as Canada recovered from the COVID-19 pandemic, the federal government provided over 33,000 businesses with innovation and growth support, valued at $4.5 billion, through 134 federal programs.
- In 2021, small and medium-sized enterprises (those with fewer than 500 employees) accounted for 96% of all program recipients and over three-quarters of total support value.
- Several indicators are consistent with the notion that business innovation and growth support (BIGS) programs helped businesses recover from the pandemic.
- The revenues of BIGS-supported corporations expanded by 16% in 2021, three times higher than in 2020. Their export revenue rose 15% during the same period, after declining by 4% from 2019 to 2020.
- BIGS recipients continued to innovate in 2021, as their research and development expenditures rose by 12%, comparable with the 11% increase from 2019 to 2020.

For more information: *The Daily*—Business innovation and growth support, 2021.

Patent activity scaled back prior to the COVID-19 pandemic

Chart 7
Number of patents



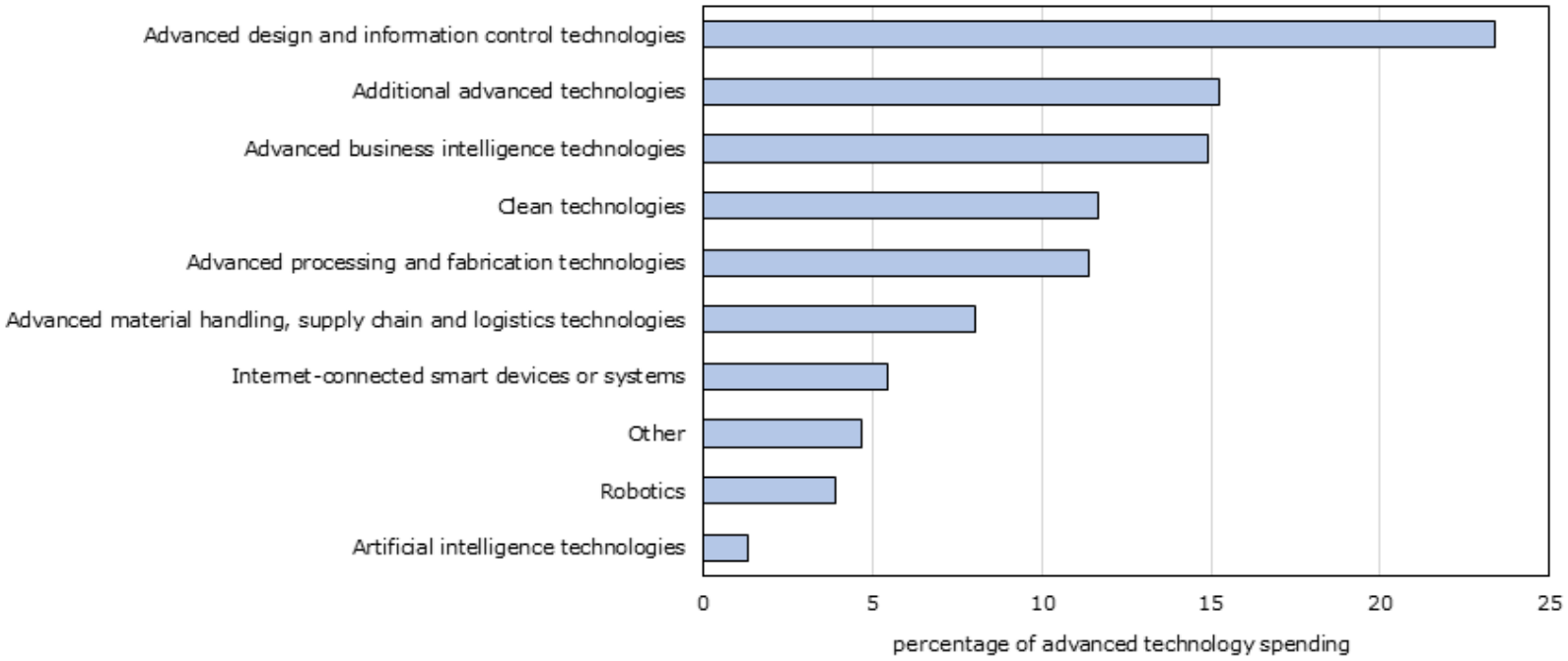
Note: CIPO= Canadian Intellectual Property Office; USPTO= United States Patent and Trademark Office.
Source: Abbes, Lafrance-Cooke and Leung (2022) "Patenting activity of women-owned businesses in Canada".

- 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.
- While over one in five businesses owned an intellectual property (IP) asset in 2022, only about 6% owned patents (Survey of Innovation and Business Strategy, 2022).
- New research at Statistics Canada shows that Canadian multinationals demonstrated superior IP generation than foreign-owned multinationals, with four in five high-tech patent applications originating from Canadian-controlled entities.
- Revenues for IP rebounded in 2021. Businesses in Canada performing research and development generated more revenue from the use of their IP than ever before, as receipts rose 37% to $8.9 billion. At the same time, payments for IP increased 34% to $2.2 billion.

For more information: *The Daily*—Survey of Innovation and Business Strategy, 2022 and Innovation in focus: Exploring trends in the development of advanced technology through patent applications.

Adoption of disruptive technologies is in its early stages

Chart 8
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.

- According to the 2022 Survey of Advanced Technology, almost two-thirds of businesses (62.1%) have adopted at least one type of advanced technology. However, spending levels are modest, and take-up rates for disruptive technologies are comparatively low.
- Only 3.1% of businesses reported using artificial intelligence, while 2.1% reported using robotics.
- The top three obstacles reported by enterprises that did not adopt advanced technologies were low returns on investment or long payback periods from such investments (40.6%), challenges recruiting skilled staff (36.7%) and difficulties integrating new advanced technologies with existing systems (34.7%).

For more information: *The Daily*—Survey of Advanced Technology, 2022.

Comparatively low spending on advanced technologies

- While a majority of businesses covered by the 2022 Survey of Advanced Technology adopted at least one type of advanced technology, capital outlays on advanced technologies from 2020 to 2022 totalled only $6 billion. By comparison, private sector expenditures on research and development during this three-year period amounted to $79 billion.
- Of businesses that did not incur any capital expenditures on advanced technologies from 2020 to 2022, about 6 in 10 reported that they were not applicable to the enterprise's activities. Similarly, one in five non-investing businesses reported that investments in advanced technology were not necessary for continuing operations.
- In the second quarter of 2024, about one-half of businesses reported that they did not have any plans to adopt or incorporate AI or other advanced digital technologies over the next 12 months (a group that includes non-adopters and past adopters). One-third of these businesses reported that digital technologies were not relevant to their organization.
- Low adoption rates and expenditure levels for disruptive technologies raise questions about how well-positioned businesses are to reap the benefits of major technological advances. In the second quarter of 2024, 6% of businesses reported using artificial intelligence for producing goods or delivering services over the previous 12 months.

For more information: *The Daily*—Survey of Advanced Technology, 2022, *The Daily*—Non-residential capital and repair expenditures, 2022 (revised), 2023 (preliminary) and 2024 (intentions), Reasons for not investing capital expenditures in advanced technologies, by industry and enterprise size, Technologies the business or organization plans to adopt or incorporate over the next 12 months, second quarter of 2024 and Analysis on artificial intelligence use by businesses in Canada, second quarter of 2024.

Impacts of artificial intelligence on the workforce may be more far-reaching than earlier technological transformations

- Previous waves of automation mainly affected workers performing routine and manual tasks—artificial intelligence (AI) is expected to impact a larger segment of the workforce because of its increasing capacity to perform cognitive and non-routine tasks.
- New research at Statistics Canada has produced experimental estimates of potential AI occupational exposure and complementarity in Canada, and it was found that 40% of workers have low exposure to AI. The remaining 60% are split into two groups: workers with high exposure that have high complementarity with AI technologies (29%), and workers with high exposure and low complementarity with AI (31%).
- High earners are more likely to be in jobs that have high exposure and high complementarity with AI, while middle earners are more likely to be in high-exposure jobs with low complementarity.

Artificial intelligence is expected to have far-reaching impacts on business productivity and the nature of work

Figure 2
Potential artificial intelligence occupational exposure and complementarity in Canada

Notes: AIOE= artificial intelligence occupational exposure. The AIOE index and potential complementarity are based on Felten, Raj and Seamans (2021) and Pizzinelli et al. (2023). An occupation is considered high-exposure if its AIOE index exceeds the median AIOE across all occupations (6.0) and considered low-exposure otherwise. Similarly, an occupation is considered high-complementarity if its complementarity parameter exceeds the median complementarity across all occupations (0.6) and considered low-complementarity otherwise. Occupations in this chart are based on the 4-digit National Occupational Classification (NOC) 2016 version 1.3 converted from the United States Standard Occupational Classification (SOC) 2018. Of the 500 NOC occupations, 10 occupations which represented less than 1% of Canadian employment, were excluded due to a lack of Occupational Information Network (O*NET) data for computing the AIOE or complementarity parameter.
Sources: Forthcoming Mehdi and Morissette (2024) and Occupational Information Network (O*NET) version 28.2.

Takeaways

- There is little evidence from Canada's official productivity statistics that innovation and advanced technology adoption are translating into sustained improvements in business efficiency beyond their measured impacts on capital and labour. This aligns with a longstanding concern: the need for businesses to more fully exploit the benefits of innovation and advanced technology to expand output and increase labour productivity.
- Recent data from innovation and technology surveys highlight the positive linkages between competition, innovation and business efficiency. While business expenditures on research and development (R&D) and receipts from intellectual property are rising, concerns over the intensity with which businesses are investing in knowledge capital persist, especially in relation to many competitor economies. R&D intensity remains low, while patent applications scaled back measurably prior to the pandemic.
- Business investment in disruptive technologies, widely touted as a potential game changer for productivity, is in its early stages. Artificial intelligence (AI) adoption rates were about 3% in 2022, with little capital spending on emergent technologies. While 6% of businesses reported using AI in the second quarter of 2024, over one-half of businesses were not planning to adopt or incorporate AI or other advanced digital technologies over the coming year (a group that includes both non-adopters and past adopters).

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