

ARTIFICIAL INTELLIGENCE IN CANADA*

Economic Research And Analysis, SRRB/SIPS
Innovation, Science and Economic Development
September 2024

*AI assistance: Images in this presentation are generated by
Microsoft Copilot



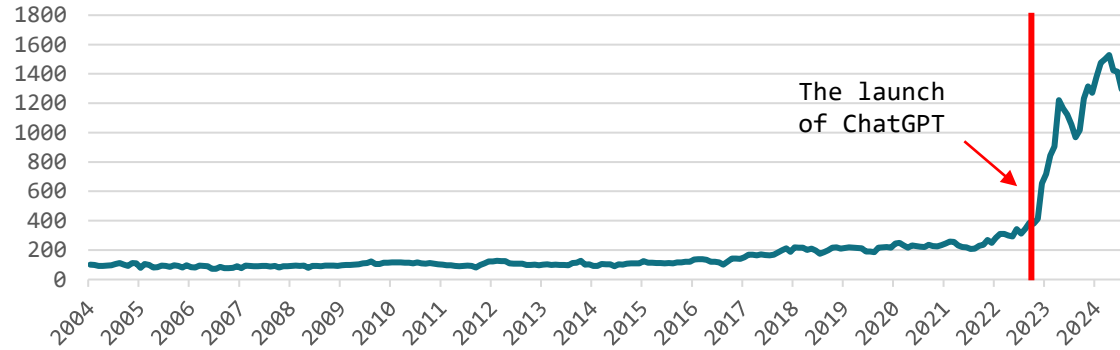
CONTEXT

- ❑ The rise of Artificial Intelligence (AI), starting slowly in the 2nd half of the 2010s, ...
 - E.g., Netflix and Amazon recommendations, digital voice assistance, google search
- ❑ ... has taken off particularly rapidly since the launch of ChatGPT in Nov 2022
 - E.g., chatbots, self-driving cars, content creation, e-health, e-learning
- ❑ While the economy has benefited from AI and its adoption, challenges also emerge
 - E.g., discriminatory pricing, built-in human bias, lower adoption among smaller and older firms
- ❑ This deck examines how AI impacts Canadian economy, and more broadly, why it matters

AI, PARTICULARLY GENERATIVE (GEN) AI, HAS GROWN EXPONENTIALLY

AI-related Google search in Canada surged by over 600% in the past 5 years

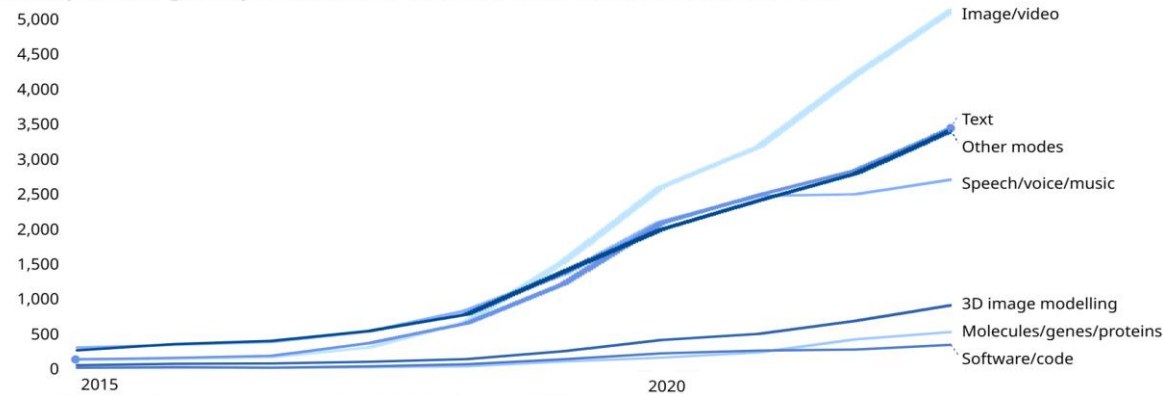
AI-related Google Trend Index in Canada (2004 = 100)



Source: Authors' calculation using Google Trend with Keywords "AI", "Artificial Intelligence", "Machine Learning", "IA", and "Intelligence Artificielle"

GenAI patents - representing 6% of all AI related patents - are commonly used in image and video

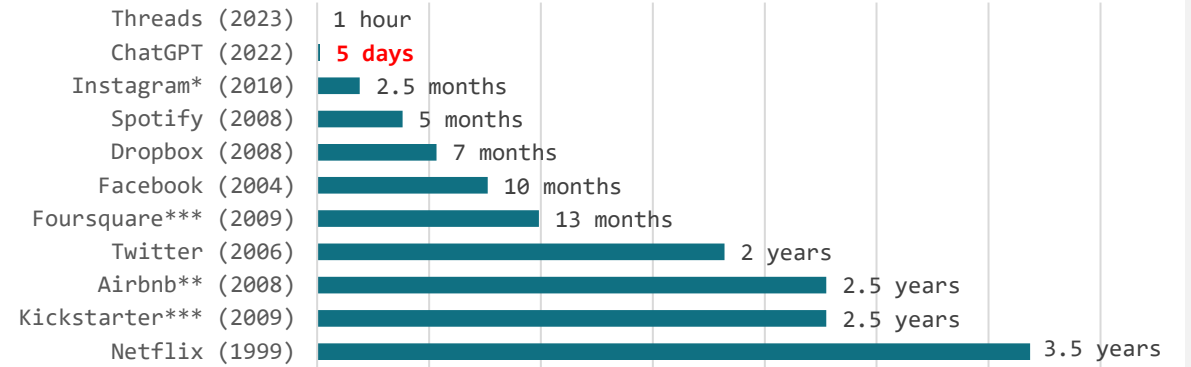
Development of global patent families in the different GenAI modes, 2014-2023



Source: WIPO, based on patent data from EconSight/IFI Claims, April 2024.

ChatGPT shattered the record as one of the fastest digital platform to reach 1 million users

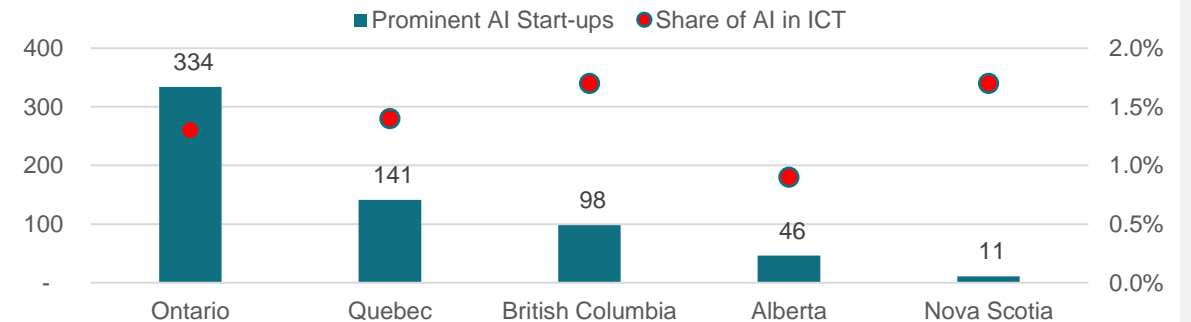
Time Taken to Reach 1 Million Users



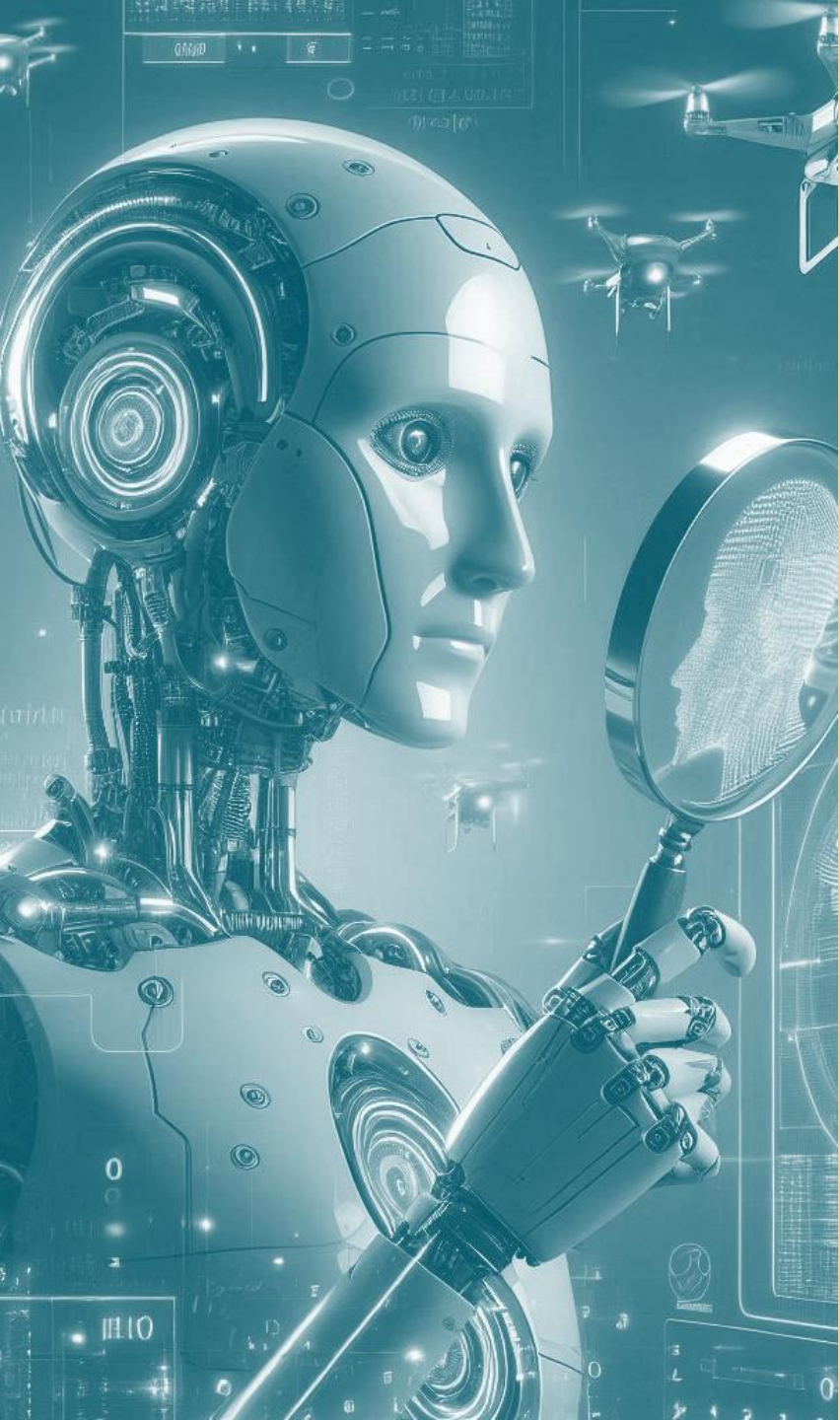
Source: Statistica, company announcement via Business Insider/LinkedIn.
Note: *1 million downloads, **1 million nights booked, ***1 million backers

At 1.7%, NS and BC are home to the most AI-focused ICT sector despite ON tops the total #AI startups

Number of prominent AI start-ups (left) and their shares in the ICT sectors (right), 2020

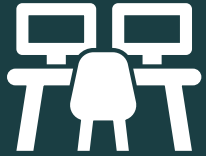


Source: Authors' calculation from University of Toronto (2022) and Statistic Canada



1. ECONOMIC IMPACT?

AI HOLDS MUCH PROMISE FOR CANADA ...



8%

Boost in labour productivity by 2030



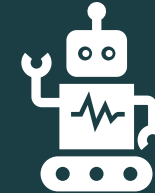
2%

Contribution to Canada's GDP



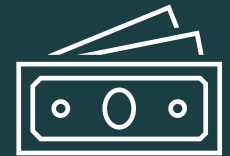
\$180B

Annual contribution to the Canadian economy by 2030



\$5B

From the creation of new Gen AI products and services



25%

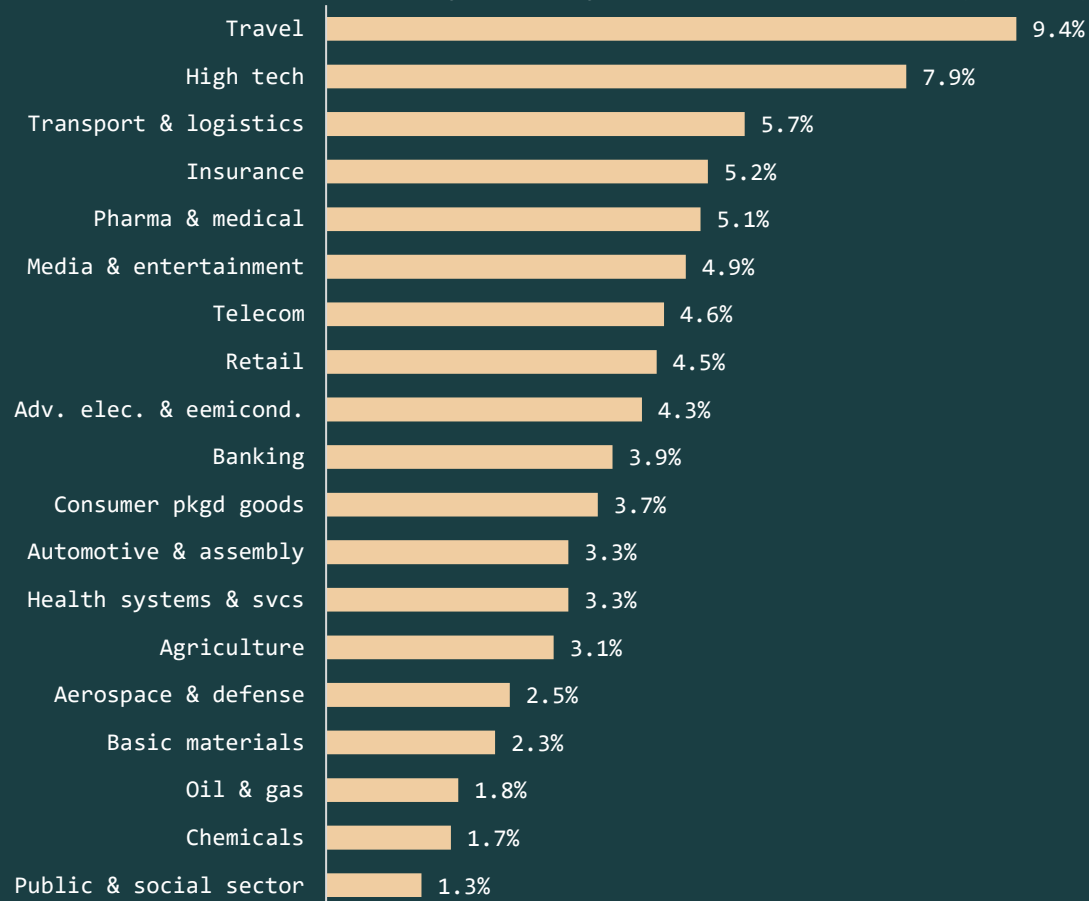
Wage premium

Possible Scenarios

... WITH MANY EXPECTING POSITIVE GAINS ...

Sectors like transport, ICT and finance are among those expecting to gain the most from AI

Estimated median impact of AI by industry as a share in revenue (percent)



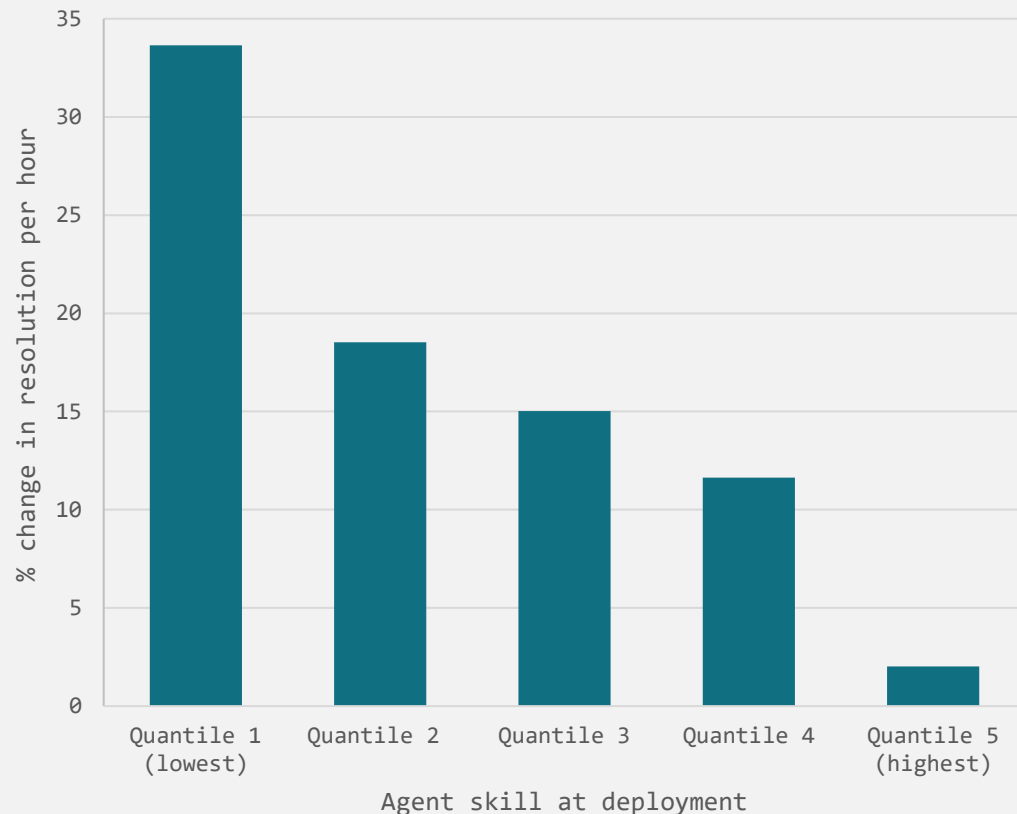
Source: McKinsey & Company (2018).

- Gains from AI are uneven with the most gains expected in
 - Sectors like travel, transport and logistics, ICT and finance (McKinsey & company 2018)
 - Tech centres like Toronto, Waterloo and Vancouver (Conference Board of Canada 2024)
- Younger businesses have more positive views on the use of Gen AI (Conference Board of Canada 2024)
 - Main motivation to use Gen AI is to help save employees time to work on more important tasks and create more value
 - Most startups (63%) do not consider implementing AI would reduce headcount, with the remaining unsure (30%) or very few (7%) consider it so
 - Two-thirds of startups have found the use of Gen AI has already made them more competitive

... YET EVIDENCE THUS FAR HAS NOT BEEN QUITE AS ROSY

AI deployment is expected to increase labour productivity of low-skilled workers far more than that of their high-skilled counterparts

Impact of AI on productivity, by skill level at deployment



Source: Brynjolfsson et al. (2023).

Note: Impact of AI on productivity is measured by resolutions per hour.

- The impact of AI on workers is mixed
 - Level up productivity by reducing productivity differentials between the skilled and the less-skilled (Noy and Zhang 2023; Peng et al. 2023; Brynjolfsson et al. 2023)
 - Unlock new powers yet bring on new risks (Dell'Acqua et al. 2024)
 - Undermine expertise (Fugener et al. 2021; Agarwal et al. 2023; Mullainathan and Rambacahn 2024)
- Investment in and adoption of AI technologies remain critically low in Canada, lagging peer countries
- Productivity gain varies widely and can take decades to realize
 - Acemoglu (2024) : +0.55-0.71% increase in total factor productivity over the next 10 years
 - Goldman Sachs (2023) : +1.5% annual increase in US productivity over 10 years
 - TD (2024) : +0.5%–0.7% annual increase in Canadian productivity over the next 10 years

OUTLINE* OF THE PRESENTATION

1. Economic Impact?
2. Definition of AI and Canada's AI Landscape
3. Investment and Capital Deepening
4. Innovation and Technology Adoption
5. Human Capital and Skills
6. Policy Implications

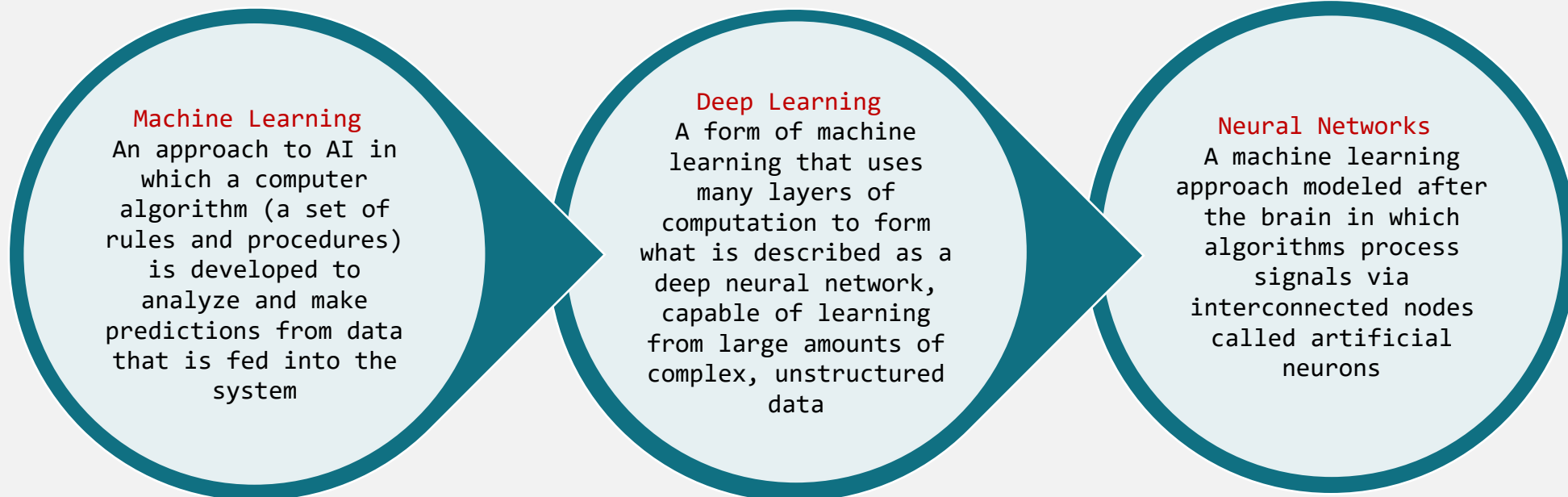
* Thankfully, this list covers all ChatGPT suggestions when prompted to “provide a structure for an exhaustive presentation on the economic implication of AI in Canada”.



2. DEFINITION AND CANADA'S LANDSCAPE OF AI

WHAT IS ARTIFICIAL INTELLIGENCE (AI)?

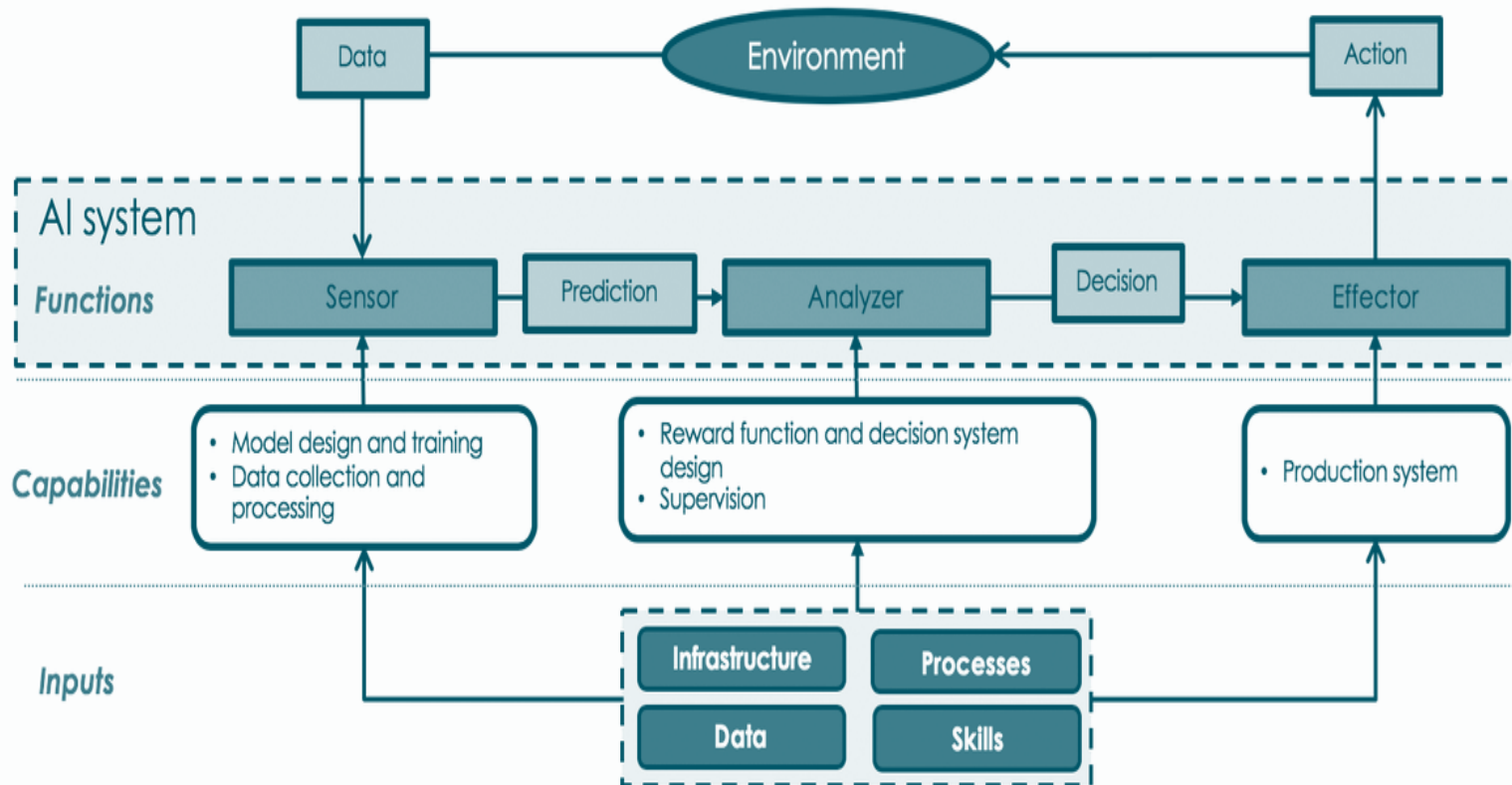
- No consensus on the definition of AI but it is commonly referred to an AI system as ...
 - A broad field covering a large range of different technical approaches, with multiple techniques often used in combination to deliver a specific function. It generally aims to create machines that are capable of tasks that otherwise require human intelligence to perform
- According to the OECD working group, an AI system is ...
 - “A machine-based system that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments. Different AI systems vary in their levels of autonomy and adaptiveness after deployment.”
- Key elements to an AI system* include the following



*See [Annex 1](#) for a systematic overview of AI and subfields.

WHAT IS AI? (CONT'D) – AN ILLUSTRATION

Structure of An AI System



Source: Mateos-Garcia (2018).

Industry	AI application
Information and cultural industries	Social media platforms use AI to maximize user-specific contents of interest based upon previous interactions
Health care and social assistance	AI-based cancer screening helps predict patient-specific at-risks level of cancer
Retail	Personalized shopping experience through AI-powered product recommendations based upon online browsing and purchase patterns
Waste management	Smart waste sorting systems uses AI-powered robots and computer vision to automatically sort recyclable materials from waste
Transportation and warehousing	Autonomous vehicles use a combination of AI technologies, including machine learning, computer vision, and sensor fusion, to navigate roads, detect obstacles, and make real-time driving decisions

CANADA'S AI ECOSYSTEM AT A GLANCE

Businesses



1,500 companies developing AI solutions, and 670 prominent AI start-up



US\$15.2B in venture capital invested in Canada's AI sector from 2012 to 2023



Over 140,000 AI professionals in 2022-23, a 29% increase from previous year

Innovation



3% of the world's top-tier AI researchers, ranking 6th globally



1st in the G7 for AI related scholarly output per capita since 2019



57% yearly increase in AI patent filings by Canadians in 2022-23

Governance



First country in the world to launch a national AI strategy.



Scale AI, a world renown AI Global Innovation Cluster, calls Montréal home



\$5 billion of federal public funding invested in AI related measures since 2017

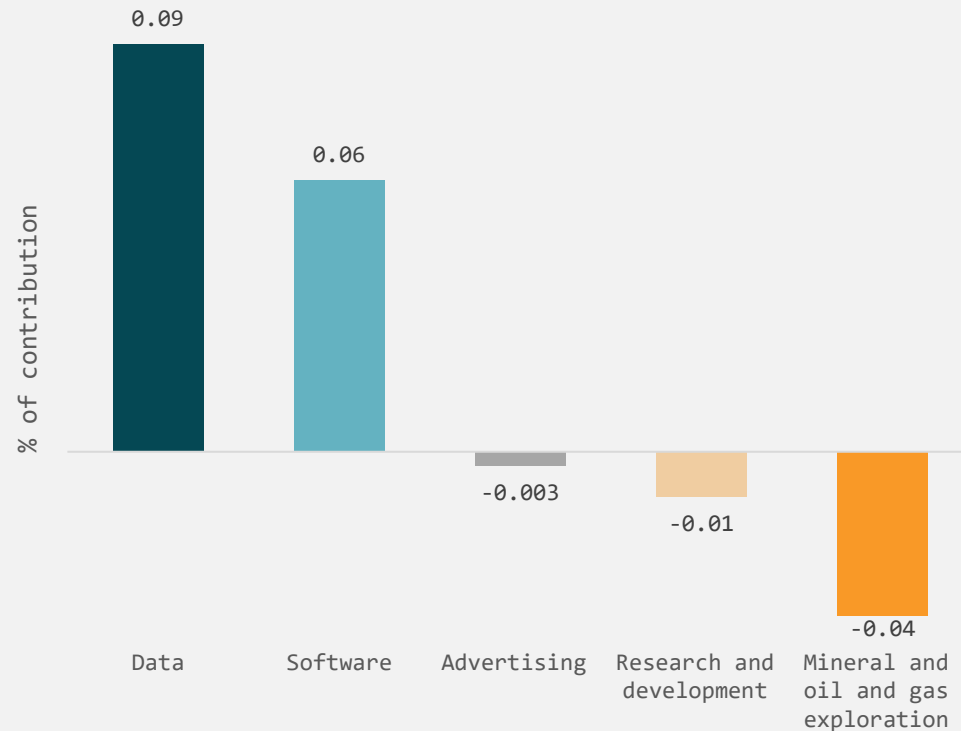


3. INVESTMENT AND CAPITAL DEEPENING

AS THE MOST IMPORTANT FACTOR IN CAPITAL DEEPENING, DATA AND DATA INFRASTRUCTURE ARE ESSENTIAL TO CANADA'S AI FUTURE

Intangible capital accounted for about 1/4 of the total capital deepening despite Canada's post-2000s slowdown in productivity growth

Contribution to labour productivity growth in 2000-2019, selected intangible assets (%)



Source: Allen, Gu and Macdonald (2023).

- Data has been the most important contributor to Canada's productivity growth among intangibles post the 2000s (Allen et al. 2023)
- Canada has a fast-growing data infrastructure
 - In 2023, Canada host 117 data center facilities across 22 cities, with an addition 13 upcoming (Research and Market 2024)
 - Estimated at \$6.9 billion and is expected to grow 10.2% over the next 5 years, data-center market across Canadian cities is world-class in availability, renewability and cost-efficient power as well as its regulatory environment (Cushman & Wakefield 2024)
- To ensure its digital future, Canada must not overlook other key aspects of AI infrastructure, both tangible and intangible
 - Computational power, pipeline and fiber development
 - Data ownership and quality are equally important as data creation and storage

ALBEIT RECENT INVESTMENT, CANADA CONTINUES TO LAG IN AI INVESTMENT AND COMPUTE

Canada's computing capacity ranks the lowest among G7 peers

Top 500 supercomputers in the world by country

Country	Number of supercomputer in top 500	Unadjusted compute performance capacity	Per capita performance	GDP adjusted performance	Core performance (petaFLOPS)
United States	171	90.4	10.6	7.6	3725.8
Japan	29	16.3	7.6	8.5	669.8
Italy	11	8.5	5.6	8.9	351.8
Germany	40	6.2	1.9	3.1	256.3
France	24	4.2	2.4	3.2	173.2
United Kingdom	16	2.0	1.2	1.4	81.7
Canada	10	1.0	1.0	1.0	41.2

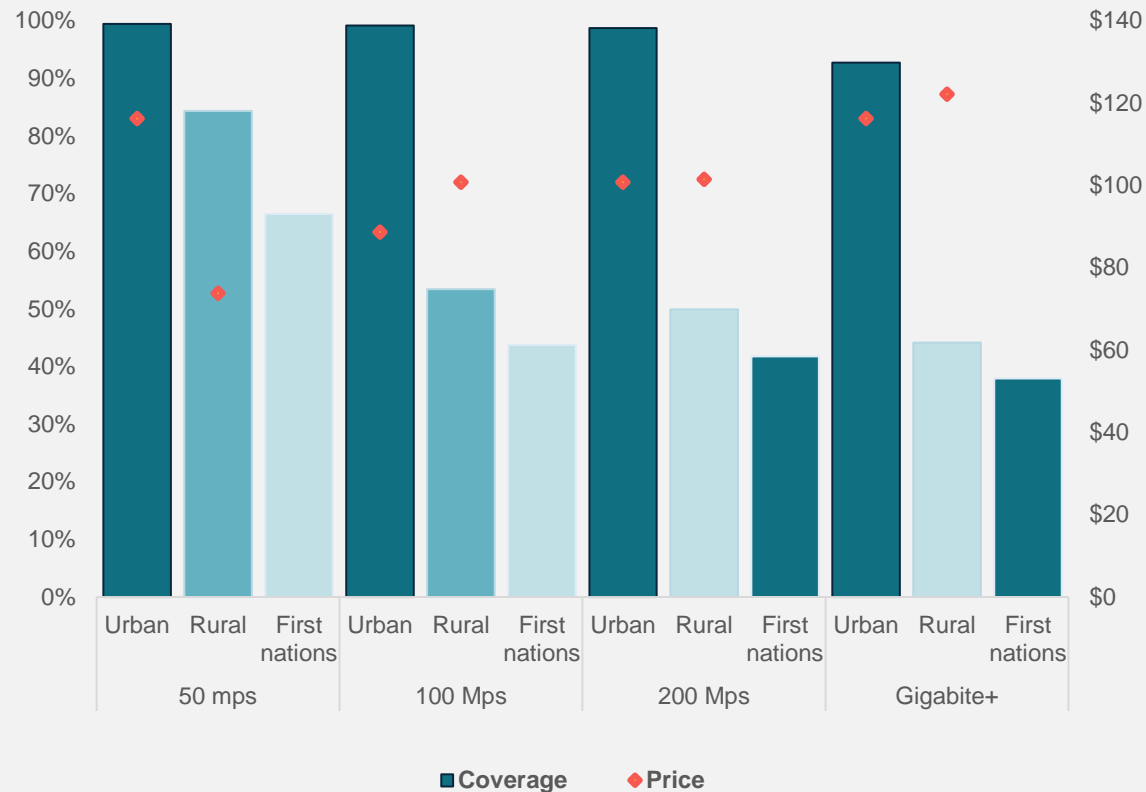
Source: Top500.org and Dobbs and Hirsch-Allen (2024).

- AI systems require considerable computational power, hardware and energy cost (Giattino et.al 2023)
- Canada's AI investment remains critically low
 - In 2020-2022, capital expenditures in AI totaled only \$77 million (or 1%) across all advanced technologies (SAT 2022)
 - Venture capital invested in Canada's AI only totaled US\$449 million in 2023, with a volatile share of total funding due to competition from other emerging sectors like finance and insurance, healthcare and biotech (OECD.AI 2024)
- The performance of Canada's 10 supercomputers is far behind G7 peers (Dobbs and Hirsch-Allen 2024)
 - It takes 100 days for Canadian computing resources to train a GPT-3 model compared with one single day in the US
 - Only one of these 10 supercomputers is funded by the private sector, with the other nine partially or fully funded by the federal governments, contrasting to two in five supercomputers in the US

BUILDING A FUTURE-PROOF DIGITAL INFRASTRUCTURE GOES BEYOND BROADBAND

Digital divide in broadband availability and affordability by speed and region

Broadband coverage percentage (%), left) and price per internet package (\$), right)



Source: CRTC (2022) on broadband coverage and ISED (2023) on the price of internet packages.

- Digital divide persists despite considerable improvements in recent years
 - As of 2022, 99% of Canadians in urban areas have broadband coverage, compared to 67% in rural areas and 50% in First Nations reserves areas (CRTC 2022)
 - Depending upon the speed of access, Canadian broadband costs about 25-40% more than the G7 average (ISED 2023)
- Affordability and complementary skills can help ensure Canadians to take advantage of digital- and AI-enabled opportunities

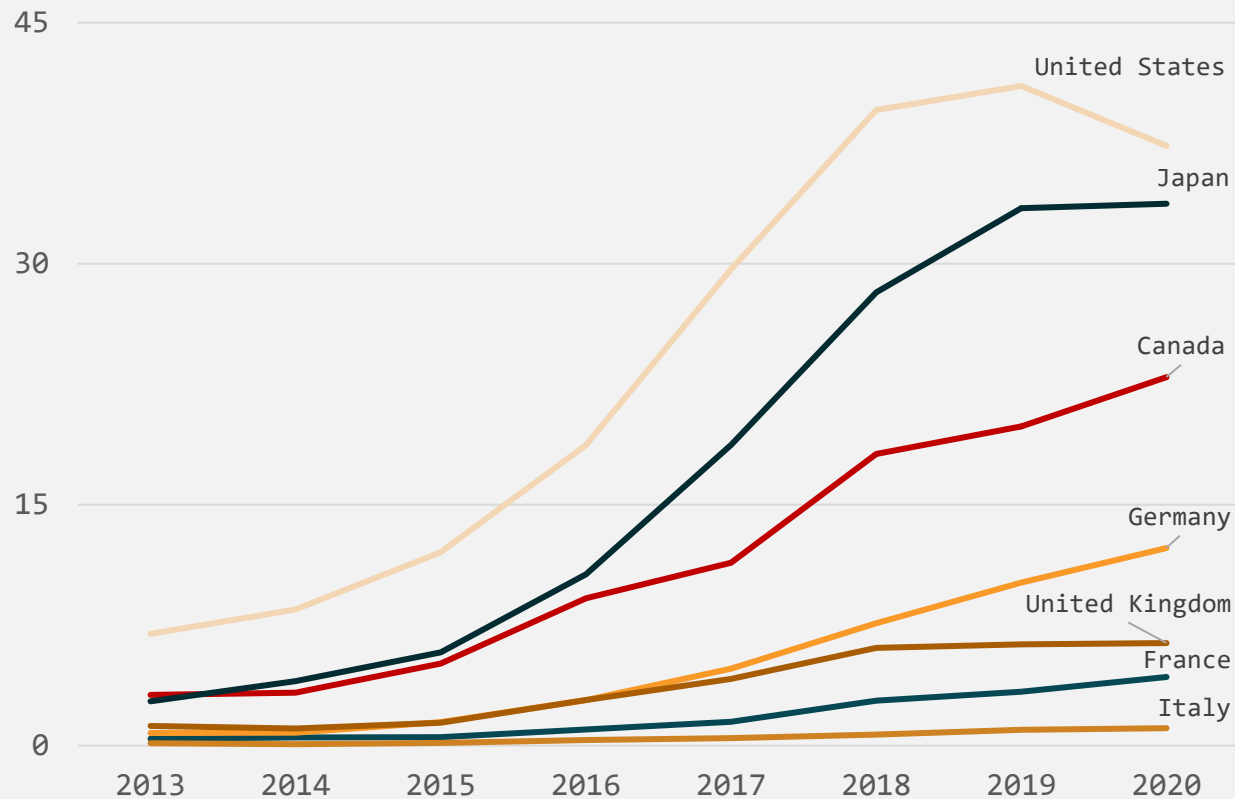


4. INNOVATION AND TECHNOLOGY ADOPTION

WHILE CANADA IS AT THE FOREFRONT OF AI INNOVATION ...

Canada Ranks 3rd Among the G7 for Number of Patent per capita

Patents related to artificial intelligence* submitted in the selected country's patent office in 2020, per million residents



Source: Giattino et.al (2023)

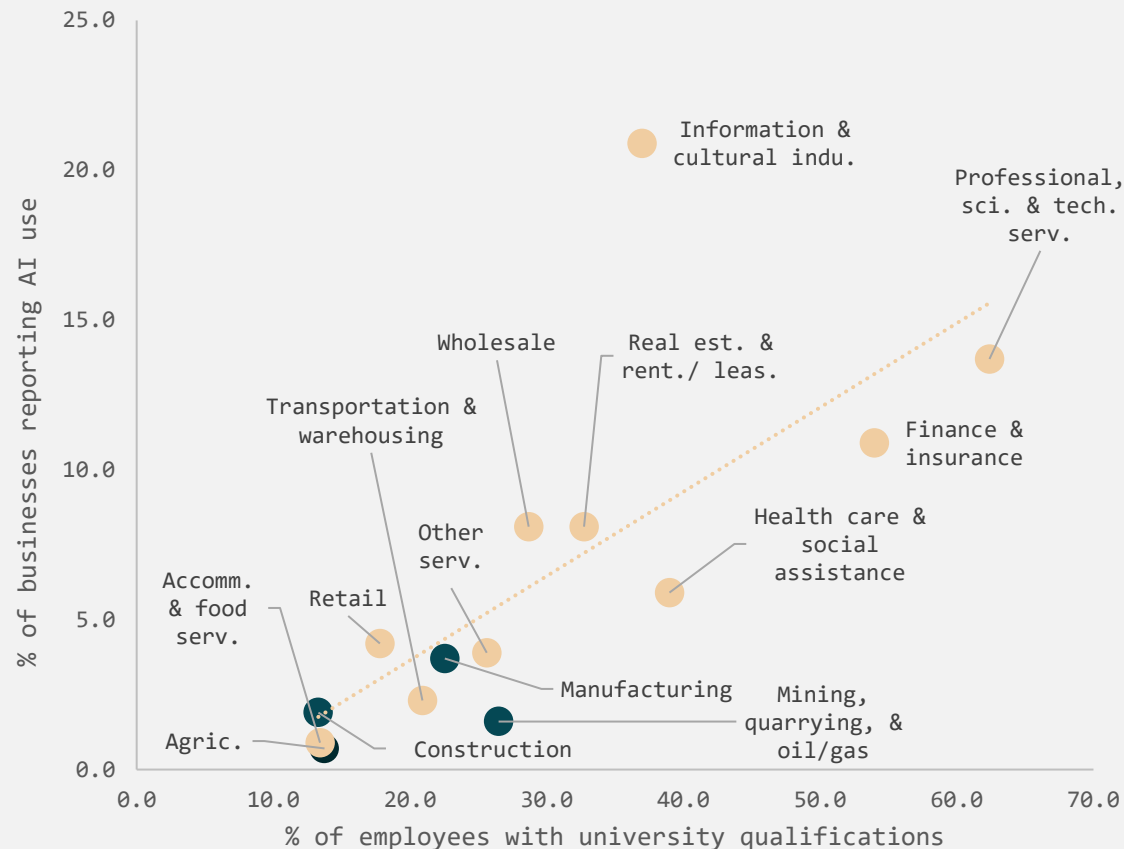
Note: *submitted in the selected country's patent office.

- Canada is among the leading nations in AI innovation (see chart)
 - Ranked 3rd in the G7 in patent applications per capita
 - AI Patent filing has also grown considerably, by 2020 it was 10 times the volume as in 2013.
 - Growth in patent filing by Canadian researchers averaged 31% annually between 2013 and 2017 (Elias et.al. 2019)
- Like the rest of the world, GenAI is the fastest growing fields in Canada between 2010 and 2023 (WIPO 2024)
 - Canada ranked 5th in #GenAI scientific publications, with 1,738 publications
 - The University of Toronto (UofT) ranked 17th in the most active institutions in the field of GenAI with 336 scientific publications
 - Canada ranked 4th in #citations of GenAI publications, with 44,972 citations
 - The UofT and University of Montreal are upon the top-20 in publication citations in the field, with 20,330 and 8,845 citations respectively

... ITS ADOPTION REMAINS LOW AND CONCENTRATED IN THE SERVICE SECTOR

AI adoption is strongly linked to higher skilled employment in Canada

Link between businesses reporting using AI and share of employee with a university qualification



Source: Authors' calculations based on the Labour Force Survey-Public Use Microdata File and the Canadian Survey of Business Conditions 2024 Q2.

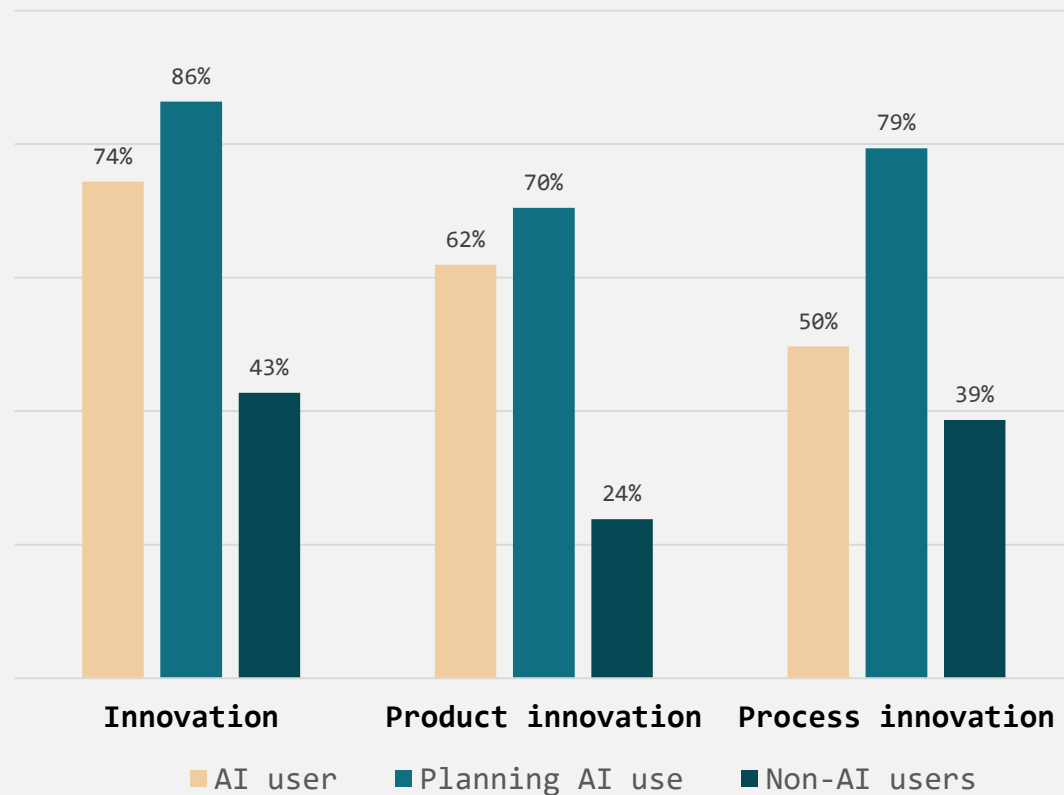
- Technology progression largely depends upon past technologies adopted. Despite that AI is among the fastest growing technology adopted (SAT 2022)
 - A majority (77%) of businesses that reported using AI started doing so in the last three years
- Canadian businesses have middling or low adoption rates
 - Across OECD countries in terms of cloud computing, internet of things, and big data analytics (OECD-ICT Access and Usage by Businesses 2021)
 - Its rate of AI adoption remains low and grew relatively slowly, from 3% in 2021 to 6% in 2023 (SDTIU 2022; SAT 2022; SIBS 2022; CSBC 2024), compared to 25% in South Korea
- Service-providing industries are predominantly early adopters of AI than goods sectors
 - Likely reflecting industrial skills composition as high-skilled industries tend to adopt AI at a greater rate

Source: Survey of Digital Technology and Internet use (SDTIU) 2022; Survey of Advanced Technology (SAT) 2022; Survey of Innovation and Business Strategy (SIBS) 2022; Canadian Survey of Business Conditions (CSBC) 2024 Q2.

... AND AMONG INNOVATIVE AND LARGE FIRMS ...

Firms that adopt AI technologies are notably more likely to innovate

Share firms that reported innovation by usage or planned usage of AI technologies (percent)



Source: Authors' calculations based upon the Survey of Advanced Technology 2022.

- AI adopters – early and planned – are significantly more innovative than non-adopters
 - Incidence of innovation among AI users is about twice that of non-users, and nearly thrice in product innovation
- AI adoption is also more likely alongside the adoption of other advanced technologies
 - Businesses and innovators alike look to AI to support their innovative activities
 - More than 70% of heavy adopters – firms integrating more than three tech domains – reported innovation, compared to 20% of non-adopters
- Large and small innovative firms predominate early adoptions of AI
 - 92% of large AI adopters and 69% of small AI adopters are firms with innovative activities

... WITH TALENTS AND SKILLS TOPING THE FACTORS LIMITING BROADER AI ADOPTION

AI adopters confronted with obstacles different from those planning to adopt AI

Share of businesses rating an obstacle as significant (percent)

Obstacles	Small firms		Medium firms		Large firms	
	AI users	Planning use	AI users	Planning use	AI users	Planning use
Production disruption	5%	8%	15%	18%	7%	19%
Non-financial support	5%	24%	11%	16%	6%	10%
Customer resistance	5%	5%	2%	10%	5%	3%
Decisions elsewhere in org.	6%	18%	8%	8%	7%	7%
Employees resistance to change	7%	12%	13%	19%	15%	17%
Integration	9%	13%	19%	44%	17%	29%
Low return on investment	12%	31%	11%	42%	13%	21%
Financial support	12%	36%	11%	27%	8%	12%
Identifying right technology	15%	12%	14%	42%	18%	40%
Determine use case	15%	29%	15%	26%	15%	25%
Regulatory	15%	8%	8%	14%	7%	15%
Ensure security/privacy	16%	12%	21%	23%	22%	38%
Lack of training	42%	22%	24%	45%	22%	50%
Recruiting staff	47%	29%	27%	42%	33%	48%

Source: Survey of Advanced Technology 2022.

- Skills top the obstacles facing **AI adopters**
 - Two out of five AI adopters consider recruiting staff and lack of training a challenge, and ...
 - ... small adaptors are nearly twice more likely to report them than large and medium-sized firms
 - Other concerns relate to security, regulatory issues, user application, financial and non-financial support
- In comparison, **businesses planning to adopt AI** display a wide-range of concerns but more equally, pointing to the multifaceted uncertainties surrounding the new technology
 - For obstacles which firms identify regardless of size, nearly twice as many medium and large firms tend to report them than small firms

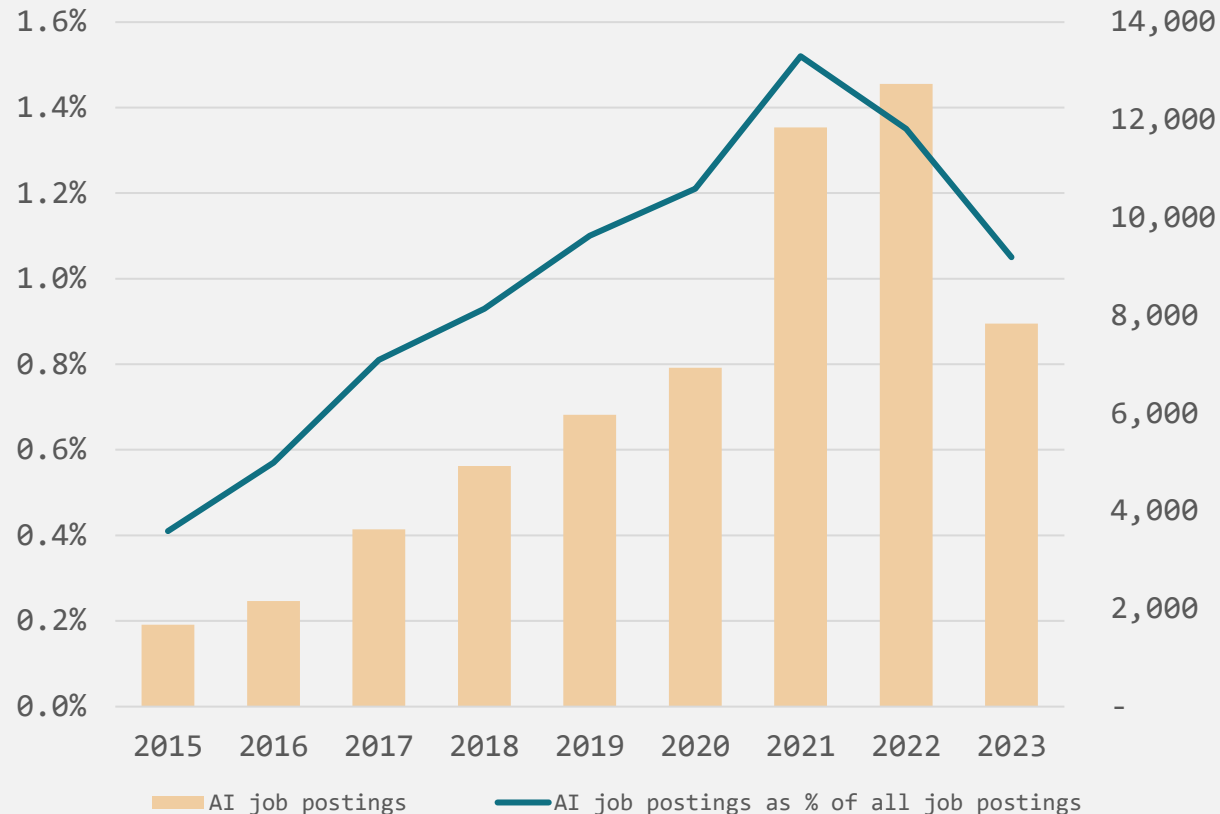


5. HUMAN CAPITAL

THE DEMAND FOR AI SKILLS IS ON THE RISE DUE TO THE HEIGHTENED USES

Demand for AI skills in Canada has accelerated in recent years

Proportions of vacancies demanding AI skills (right axis), level of jobs demanding AI skills (right axis)



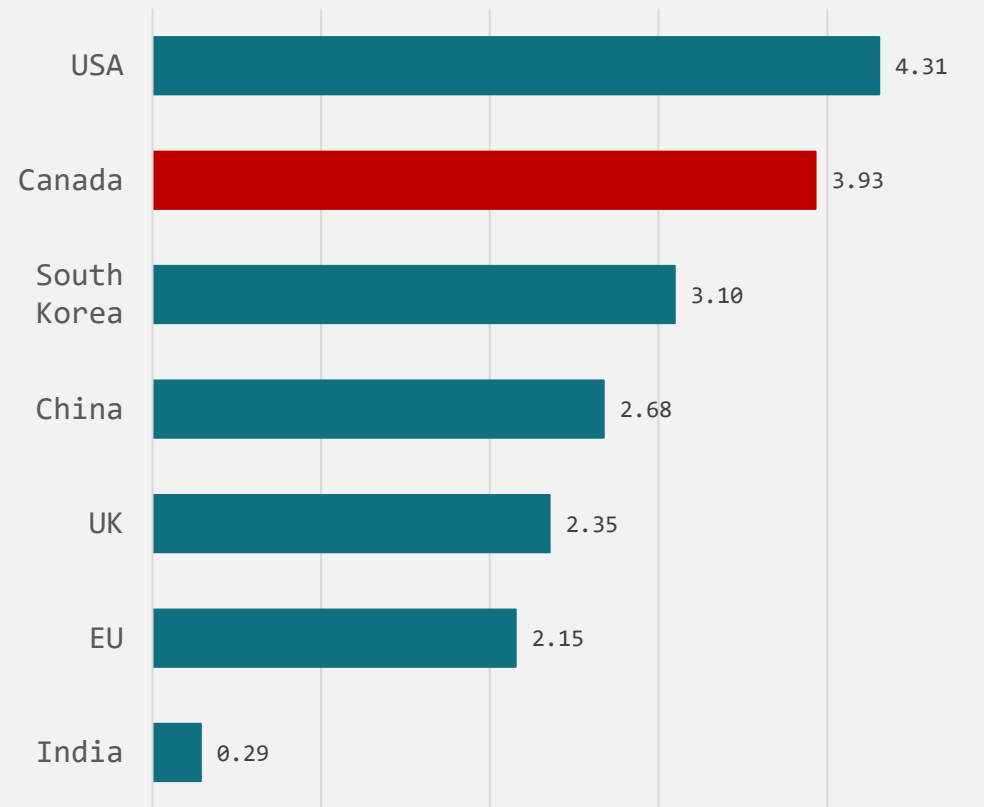
Source: Authors' calculations based upon estimates from The AI index Annual Report, Stanford University (2024) and Statistics Canada Table 14-10-0400-01.

- AI skills in job openings have risen globally and in Canada (Stanford University 2024)
 - AI-related vacancies stood at 1.05% of all job postings in 2023, up from just 0.4% in 2015
 - The slight drop in the last two years related to a stronger rise in demand in jobs providing face-to-face service post the pandemic
- The rise in demand for AI talents is most pronounced in areas of research and data science, as well as occupations that drive and support the AI ecosystem (PWC 2024)
 - ICT sector accounts for most of the increased demand for AI skills, with its share of vacancies demanding AI skills rising to 4% in 2023, from just 1% in 2015.
 - Other sectors, incl. prof. services, financial services, manufacturing and education, all with above 2% of vacancies demanding AI skills in 2023, compared with just under 1% they all had in 2015.

CANADIANS' AI TALENTS LEADS IN WORLD RANKING, BOTH IN DEPTH AND BREADTH

Canada is a world leader in AI research with the second largest per-capita AI researchers

Concentration of AI researchers, measured as country's share of global AI researchers /country's share of global population, 2022



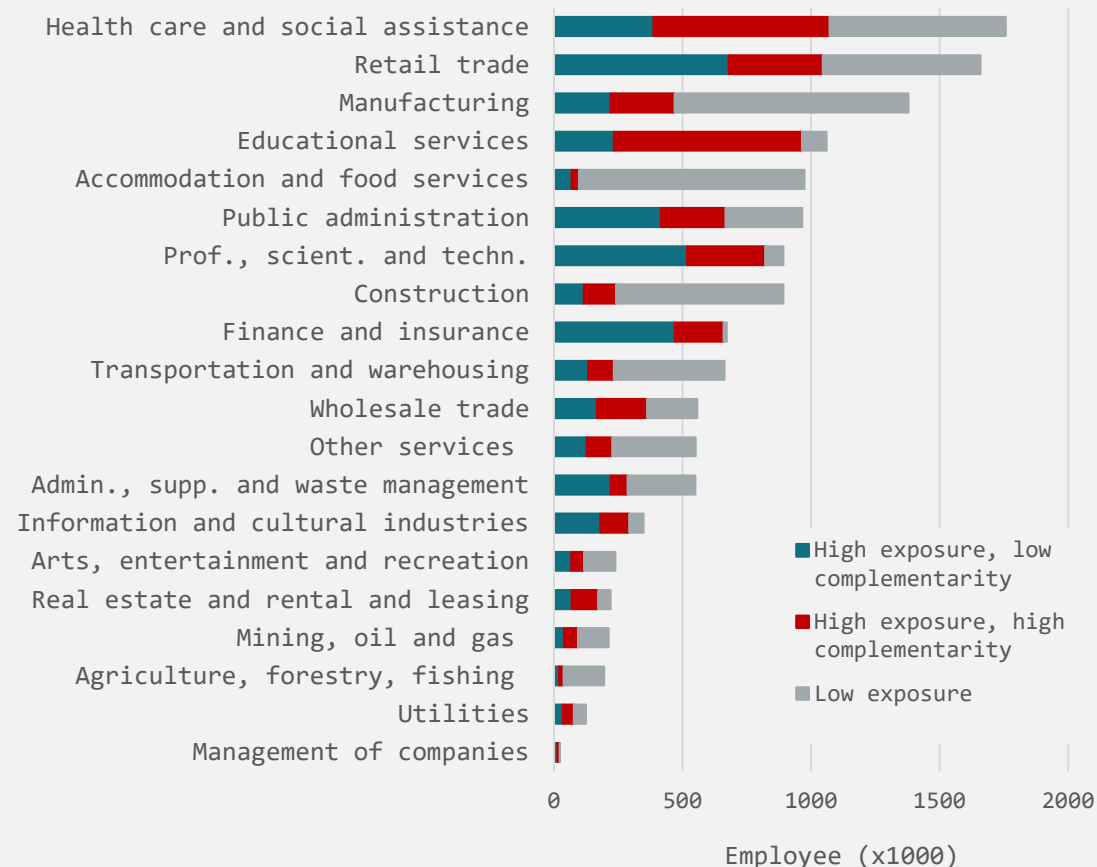
Source: MacroPolo; U.S. Census Bureau, International Database on demography; Statistics Canada Table 17-10-0009-01; and Eurostat.

- Canada is home to top AI talents across G7 countries (see chart)
 - Second biggest producer of AI researchers in per-capita #AI researchers, and first among G7 AI researcher publications per capita in 2022
- Canadians are integrating AI-related skill in all occupations, more so than others (Stanford University 2024)
 - Canada ranked top-4 countries with the highest AI skills penetration, signaling the prevalence of AI skills across occupations
 - At 1.7 times greater than the global average in 2015-2023, Canada trails only AI powerhouses like India (2.8), the US (2.2) and Germany (1.9)
- Talent pipeline has also seen some of the fastest and inclusive growths
 - Over 140,000 AI professionals in Canada in the 2022- 23 period, up 29% over the previous year (Deloitte 2023)
 - Postsecondary enrolment in AI-related subjects (i.e., math, computer sci.) has more than doubled to 5.9% over the last decade (Statistics Canada Table: 37-10-0011-01)
 - Female AI talents saw the fastest growth globally, at 41% annually in 2019-2022 and 67% in 2022 alone (OECD.AI Observatory)

TRAINING AND SKILL UPGRADING ARE NECESSARY TO UNLOCKING THE AI POTENTIAL

Different industries likely face different AI challenges

Number of employees by potential artificial intelligence occupational exposure and complementarity in Canada by industry, May 2021



Sources: Mehdi and Morissette (2024).

- Early estimates suggest that 60% of jobs are highly exposed to AI (Mehdi and Morissette 2024)
 - Nearly half of the highly exposed jobs (or 3.9 million) are augmented by AI whereas the other half (or 4.2 million) compete directly with it
- Opportunities exist across industries but not without risks
 - High-exposure + low-complementarity: Prof. sci. and tech services, finance and insurance, and information and cultural
 - High-exposure + high-complementarity: Health and education
 - Low-exposure: Accommodation and food services, manufacturing, construction, transportation and warehousing
- Training and skill upgrading are increasingly critical to a sustained transition and its success. Improving workers' collective bargaining, AI safety and ethical oversight will also be crucial to realize AI's potential for all.

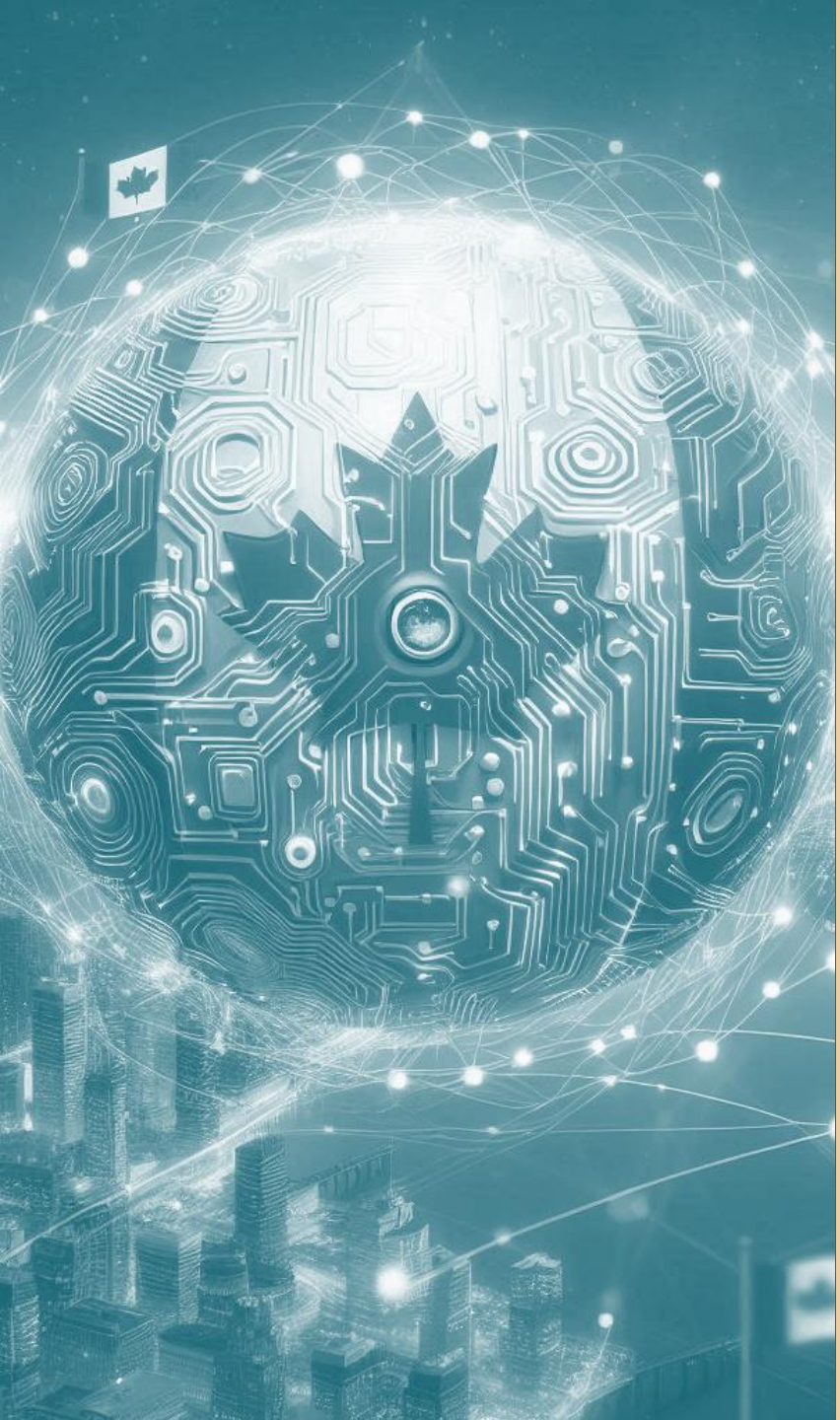
A RECAP: AI IN THE CANADIAN ECONOMY

- Opportunities

- Productivity and skills enhancing over a long run
- Forefront of AI innovation globally -- in patenting and citation -- and among innovative businesses
- World-class data center market in availability, renewability and cost-efficient power, as well as regulatory environment
- Steady supply of high-quality and multi-skilled AI talents

- Headwinds

- Low AI investment and business adoption of AI technologies, concentrating in large firms and the service sector
- Lagging computing infrastructure and performance
- Affordable and equitable access to digital infrastructure
- Slow labour market adjustment to the transformation of occupations integrating AI
- Other factors related to regulatory framework (e.g., data privacy, security, ownership and ethics)



6. POLICY IMPLICATIONS

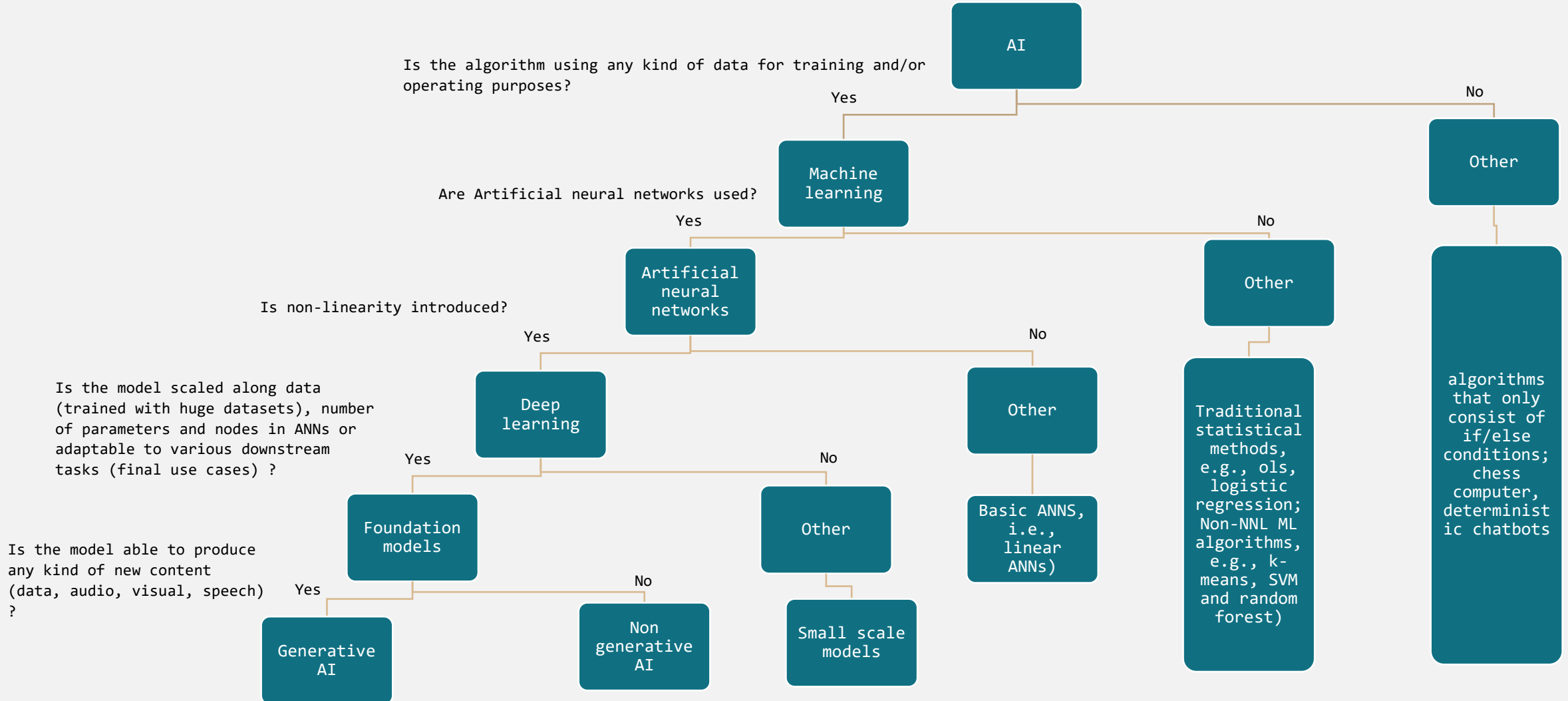
POLICY CONSIDERATIONS

- **Investment:** Incentivize private investment in R&D and digital assets such as cloud computing, AI applications and data procurement
- **Infrastructure:** Develop an equitable digital infrastructure accessible by all businesses and individuals, incl. but not limited to, access to high-quality digital infrastructure by rural and remote areas, while ensuring its affordability
- **Innovation & Adoption:** Incentivize private-sector innovations and support business adoption in AI technologies among SMEs while bolstering access to affordable consumer-facing technologies
- **Skills:** Address the AI skill gap through employees' re-training and upskilling programs; students' education in acquiring AI tools and skillsets; and through access to specialized expertise across Canada and internationally
- **Competition:** Promote market competition at all levels to help SMEs compete and succeed in the digital economy
- **Regulatory framework:** Develop the regulatory framework to guardrail data in terms of ownership, quality, privacy and ethics
- **Public education:** Raise public awareness on AI and safe AI use, demystify mis/dis-information on AI while boosting public confidence in AI
- **AI Statistics:** Ensure a timely and consistent data collection by Statistics Canada such as the Canadian Survey of Business Conditions, Survey of Innovation and Business Strategy, Survey of Advanced Technology, and Survey of Digital Technology and Internet Use



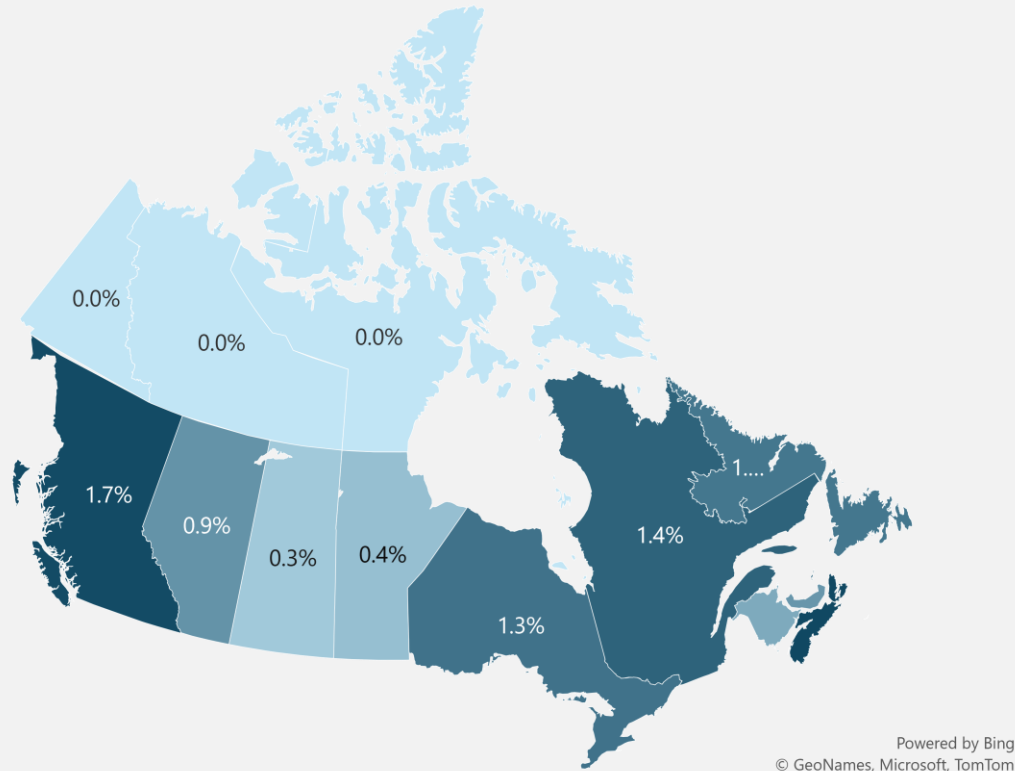
APPENDIX

APPENDIX 1: SYSTEMATIC OVERVIEW OF AI AND SUBFIELDS



APPENDIX 2: CONCENTRATION OF AI FIRMS REFLECTS REGIONAL STRENGTHS

Share of prominent AI Start-Ups Among ICT sector firms, by Province, 2020



Powered by Bing
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Repartition of Prominent AI Start-up and ICT Sector Firms by Province and Territories, 2020

Provinces	Total number of firms	ICT sector firms	Prominent AI Start-ups	Share of ICT	Share of AI in ICT
Ontario	487,909	26,260	334	5.4%	1.3%
Quebec	271,837	9,749	141	3.6%	1.4%
British Columbia	207,668	5,738	98	2.8%	1.7%
Alberta	175,434	5,043	46	2.9%	0.9%
Nova Scotia	32,329	632	11	2.0%	1.7%
Manitoba	42,955	712	3	1.7%	0.4%
New Brunswick	27,061	455	3	1.7%	0.7%
Newfoundland and Labrador	20,041	245	3	1.2%	1.2%
Saskatchewan	43,602	635	2	1.5%	0.3%
Prince Edward Island	6,955	114	1	1.6%	0.9%
Yukon	1,984	24	0	1.2%	0.0%
Northwest Territories	1,662	20	0	1.2%	0.0%
Nunavut	770	5	0	0.6%	0.0%

Source: University of Toronto (2022) Canada's AI ecosystem, and Statistics Canada Table 33-10-0267-01.

APPENDIX 3: REFERENCE

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