Maximizing Strengths and Spearheading Opportunity

Towards an Industrial Strategy for Canadian Artificial Intelligence

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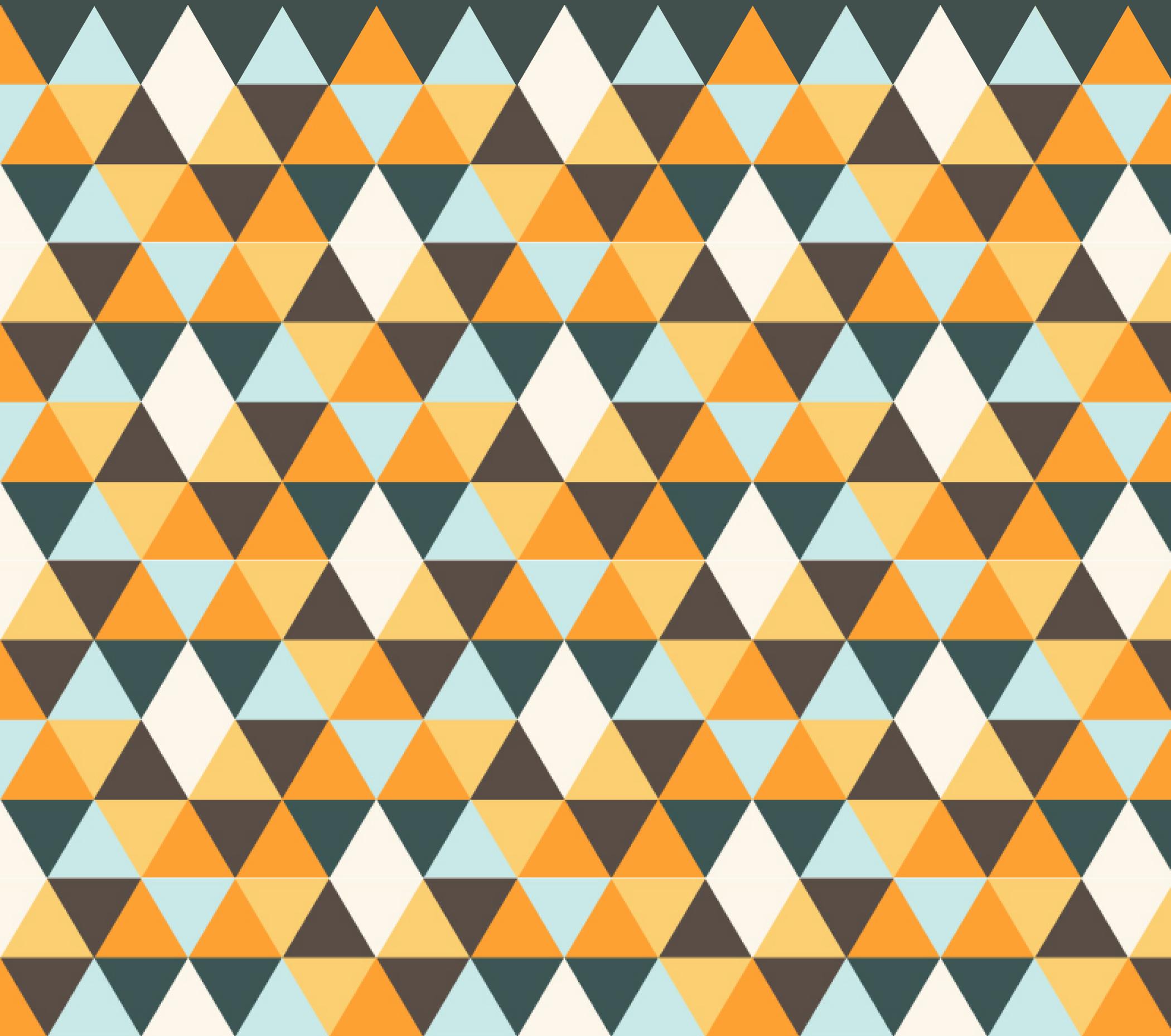
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Preface

The Information and Communications Technology Council (ICTC) is a not-for-profit, national centre of expertise for strengthening Canada's digital advantage in a global economy. Through trusted research, practical policy advice, and creative capacity-building programs, ICTC fosters globally competitive Canadian industries enabled by innovative and diverse digital talent. In partnership with an expansive network of industry leaders, academic partners, and policy makers from across Canada, ICTC has empowered a robust and inclusive digital economy for over 25 years.

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Abstract:

This paper outlines the broader aspects and landscape of Canada's existing AI policy and strategy, and suggests additional measures to pave the way for enhanced commercialization of Canadian AI, accelerated industrialization, and responsible and sustainable prosperity. Recent trends in AI and digital adoption, coupled with accelerated digital transformation, warrant an AI strategy that focuses on increased commercialization, effective governance, and an understanding of social impacts. A renewed lens on the existing national AI strategy, this industrial strategy expands on commercialization of Canadian AI, including an analysis of Canadian IP ownership. It also investigates supports needed for Canadian AI to scale, including key programs and resources, further investment in digital infrastructure, talent attraction and retention, building modern privacy legislation and industry standards, and recommendations to support responsible AI governance. On the talent side, investment in AI research—the core focus of the current AI strategy—encompasses only a fraction of future AI talent needs in Canada; a strong talent pipeline that is equitable and accountable, yet also data-centric, will be a key component of commercialization and good governance going forward. Finally, a successful industrial AI strategy must be accompanied by responsible innovation and sustainable and inclusive growth. Together, these aspects form the core of a renewed and enhanced AI industrialization strategy for Canada.

Keywords:

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Background

Canada's Budget 2021 signaled a vibrant and renewed interest on the part of the federal government in the future of Canadian-grown artificial intelligence (AI). It earmarked up to $443.8 million over ten years starting in 2021-22 to renew the Pan-Canadian Artificial Intelligence Strategy and make other significant investments in programs related to AI (such as the Industrial Research Assistance Program, Strategic Innovation Fund, and Innovation Superclusters Initiative).[1] Canada already comes equipped with many strengths in the field of AI, such as strong research communities, expert talent, and a diverse ecosystem of start-ups. Capitalizing on these strengths is critical; with a new commitment to AI R&D on the table, alongside active investments in AI business scale-up and growth, now is the optimal time for Canada to strengthen its AI leadership by focusing on commercialization.

The first edition of the Pan-Canadian AI Strategy was launched in 2017, with a $125 million budget proposal.[2] The Strategy's scope focused largely on academic research initiatives,[3] with some, albeit limited, attention paid to commercialization. Complementary policy surrounding the national strategy, dispersed among various actors, has also included components related to data ethics and privacy, innovation and industrial policy, and skills development. Although efforts have been made to advance commercialization of Canadian AI, a clear industrial strategy is necessary to guide this pathway in an increasingly digital future.

Multi-participatory and highly coordinated, an industrial AI strategy for Canada requires collaboration between government, industry, academia, civil society, and the public, as well as within government across many departments, agencies, and arms-length institutions. Such a strategy can better catalyze technology transfer, grow domestic capacity for late-stage, IP-rich R&D, and promote Canadian IP ownership, while driving responsible AI innovation and generating sustainable, inclusive growth.

Figure 1 outlines how an industrial AI strategy for Canada can build on the existing Pan-Canadian AI Strategy.
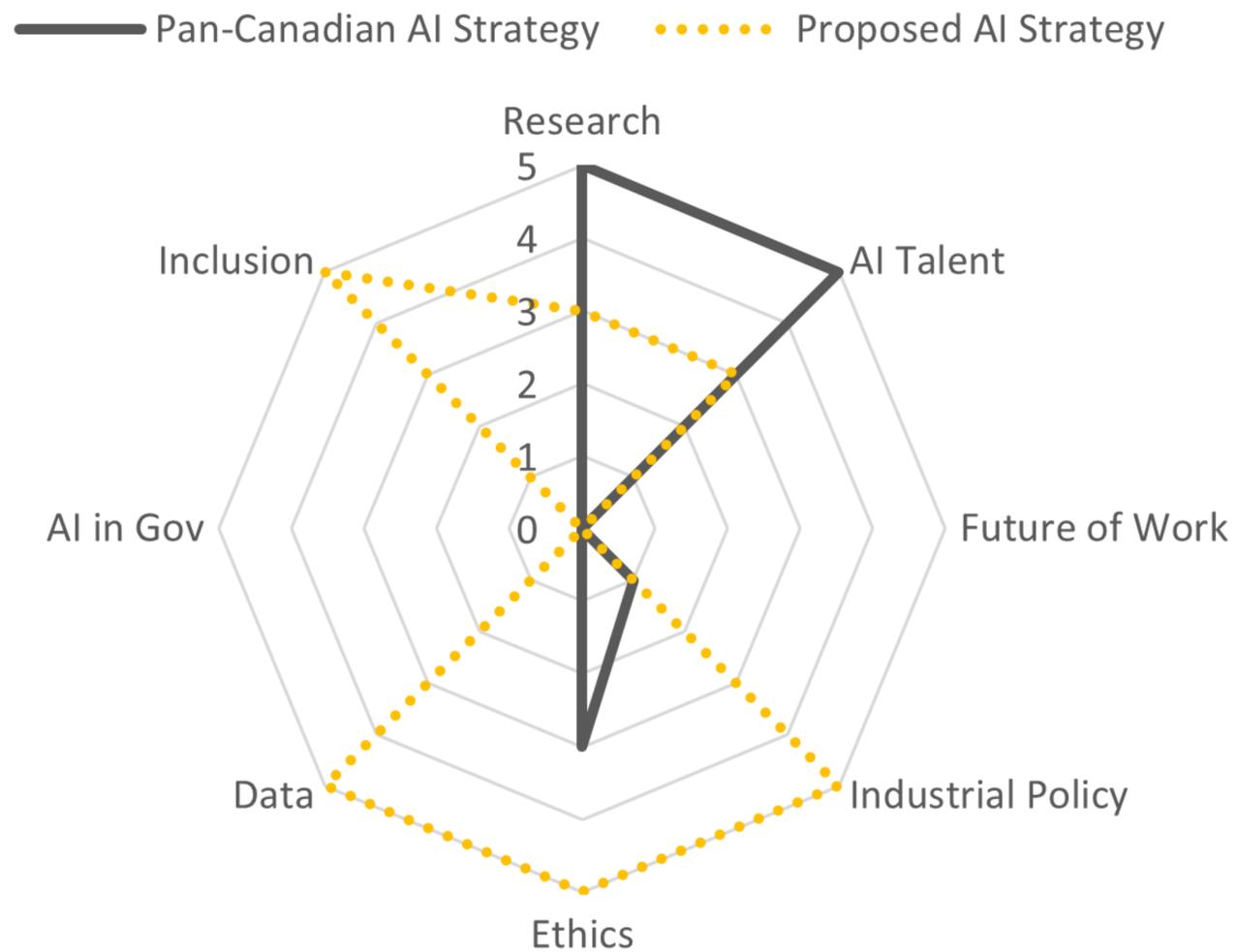
Figure 1. Core AI Strategy Areas. Source: ICTC, based on CIFAR analysis.

The following introductory section discusses the proliferating phenomenon of national AI strategies globally, highlighting their key components and the factors that make for a well-designed national industrial AI strategy. It also summarizes Canada's current national AI strategy and describes other Canadian AI policies and programs to help situate it. **Section I** describes methods of synthesizing Canadian AI policy into a clear industrial AI strategy, something that can support Canadian IP ownership and retention and help scale Canadian startups. **Section II** discusses the importance of AI talent, the skills requirements necessary to support a thriving AI ecosystem in Canada, and how best to develop, attract, and retain Canadian AI talent. **Section III** highlights the opportunity for Canada to act as a global leader in responsible AI and develop governance and industry standards that drive inclusion and accountability. Following this, the report concludes with a list of shortlisted opportunities for Canada to maximize its strengths in AI and spearhead success and inclusive prosperity.

Introduction: National AI Strategies

Key Components of National AI Strategies

Following Canada's lead in 2017, many countries have adopted national AI strategies: globally, there are an estimated 30-50 national AI strategies currently in place or under development.[4] While Canada's strategy was the first of its kind, there is much to be learned from the array of emerging national AI strategies. These strategies vary from country to country in terms of their areas of focus, objectives, policy instruments or tools, funding, and stakeholders involved. Some strategies, such as the United Kingdom's, cover nearly every aspect of AI policy, while others are more specific in scope. Nearly all AI strategies include attention to:

- Commercialization and economic benefit
- Developing AI talent and skills for success
- Responsible AI governance and ethics

These three components are the pillars of a comprehensive, sustainable, and adaptable national AI strategy.

National AI strategies employ a range of instruments to meet their objectives on each of these fronts: testing facilities, collaborative innovation labs, open innovation tools, and business advisory services on the commercialization side;[5] and research centers, funding programs, and stakeholder networks on the research side. Governance and ethics tools may also encompass things like expert advisory committees, ethics guidelines, algorithmic impact assessments (AIAs), and strategic AI procurement.

CIFAR defines AI strategies as "a set of coordinated government policies that have a clear objective of maximizing the potential benefits and minimizing the potential costs of AI for the economy and society."[6] The OECD, meanwhile notes that "strategies [serve] to maximize the economic and societal benefits of [AI]."[7] Together, these definitions paint a picture of national AI strategies as broad policy documents that strive to maximize benefit and minimize cost, determining how a government will influence and react to developments in AI.[8] While there is no clear indication of how "cost" should be interpreted, a comprehensive AI strategy considers more than just economic cost, for example, by adopting a harms prevention approach that supports sustainable, inclusive growth.

Good Design for National AI Strategies

While "good design" for national AI strategies ultimately depends on the specific national context at hand, some best practices (and purposes) exist.[9] The World Economic Forum suggests that AI strategy development should begin with "an assessment of a country's strategic priorities, strengths and weaknesses"[10] and consider things like demographic needs, citizen aspirations, resource constraints, and geopolitical realities.[11] In addition to these high-level considerations, strategies should feature tangible targets and measurable outcomes, including a plan for implementing the strategy, with consideration to timelines, budget allocations, and the roles of stakeholders.[12] Finally, because AI policy often covers such a broad range of issues, developing a national AI strategy should generally entail "a cross-government approach."[13]

Canadian AI Policy

Budget 2017 was the first Canadian federal budget to mention AI—and it did so almost 20 times.[14] Since 2017, countless federal AI policy initiatives have taken place across government, including within the Treasury Board Secretariat (TBS), Department of Innovation, Science and Economic Development (ISED), Public Services and Procurement Canada, and the Department of Canadian Heritage. Internationally, ISED and Global Affairs Canada (GAC) have also participated in engagements at the United Nations, World Trade Organization, G-7, G-20, and OECD.

At the same time, independent government bodies such as the Standards Council of Canada and Statistics Canada have emerged as potential drivers of AI governance and commercialization. CIFAR, whose work is coordinated by ISED, continues to play a critical role in supporting the AI research community, working alongside the National AI Institutes, National Research Council (NRC), National Science and Engineering Research Council (NSERC), and a range of non-governmental actors. The provinces have also adopted their own AI investment strategies supported by the local AI ecosystems. The range of organizations implicated in Canadian AI policy demonstrates a government that is committed to Canada's AI industry. It also highlights the challenge of delivering a comprehensive, unified strategy through shared or distributed policy-making authority.

The Pan-Canadian AI Strategy

When the first phase of the Pan-Canadian AI Strategy was developed by CIFAR in 2017, it became the world's first national AI strategy. Bolstered by $125 million in funding, its

primary objectives were to increase the **number of AI researchers** in Canada[15], establish **three AI ecosystems**[16], "**advance national AI initiatives** by supporting a national research community"[17], and "understand the **societal implications of AI.**"[18] To date, the Strategy's objectives have centered largely around research and AI talent. [19] However, in May 2019, the Government of Canada established an AI Advisory Council made up of experts from industry, civil society, academia, and government to "build on the Pan-Canadian AI Strategy" and act as a "central reference point" for the development of AI-related policy.[20] In February 2020, the Advisory Council released a series of "interlocking" policy recommendations addressing the "various phases of the [AI] commercialization process, from research to marketing."[21] Many of the Council's proposals are echoed in this report.

Budget 2021 signals a renewed interest on the part of the federal government in AI R&D —and in particular, the commercialization of AI innovations. The Budget proposes to invest $443.8 million over ten years to renew the Pan-Canadian AI Strategy, with commercialization accounting for over 40 % of this funding. Specifically, the Budget earmarks $185 million to support the commercialization of AI innovations; $162.2 million to help retain and attract top academic talent; $48 million to renew and enhance CIFAR's research, training, and knowledge mobilization programs; $40 million to provide dedicated computing capacity to the national AI institutes; and $8.6 million to advance the development and adoption of standards related to AI.

The initial strategy was hugely successful in building a robust base of research talent in Canada; the opportunity is now to shift that focus from the academic and research perspective to an inclusive and resilient AI industry workforce capable of adapting to and thriving in the global AI marketplace. At the same time, future iterations can leverage existing strengths to catalyze innovation and incentivize Canadian IP ownership, while converting academic research into commercial products that drive responsible AI innovation and generate sustainable, inclusive growth for Canada.

Section I: Economic Imperative for AI Commercialization

Why an Industrial Strategy for AI?

Prior to the recent proposals in Budget 2021,[22] the Pan-Canadian AI Strategy held a strong focus on academic research. This is evident both in the strategy's official goals and in the types of indicators used to assess them (e.g., academic publications, university rankings, number of AI researchers). The challenge with concentrating on the academic sector is that academic R&D is disproportionately geared towards early-stage innovation, as opposed to late stage, "patent-rich, product development and commercialization."[23]

Budget 2021 added an additional $185 million in the Pan-Canadian AI Strategy to "support the commercialization of AI innovations" and made other investments in R&D programs related to AI—these are both welcome proposals to establish the groundwork for an Industrial AI strategy.

A second and important step for a new industrial strategy for AI is to cement the importance of domestic IP production, ownership, commercialization, and retention into existing programs. These components are key to sustainable innovation in the modern digital economy, and this should be reflected across program guidelines, eligibility requirements, and funding stipulations. Likewise, domestic IP ownership, retention, and commercialization should be key considerations when choosing the right indicators for program success.

This section details opportunities for Canada to leverage its existing strength in AI research and build a strong and sustainable AI industry.

Commercializing AI Research

Recommendations that AI strategies should include attention to industrialization echo calls for a return to industrial policy more broadly. For example, Matthew Mendelsohn and Noah Zon note a recent inclination towards "bold industrial policy measures in market economies" like the US, UK, Australia, France, and the EU, "especially in emerging fields and sectors driven by intangible assets."[24]

Mendelsohn and Zon propose three "toolkit" items for holistic industrial policy: 1) rethinking public procurement practices, 2) democratizing access to capital, and 3) making government investments with keen attention to inclusive economic growth. Public procurement should strive to award contracts based on comprehensive attention to bids: for example, spanning diversity and inclusion, environmental impact, and holistic economic advantages. Democratized access to capital entails targeting underserved populations; establishing regionally focused funds; creating employee ownership trusts; generating greater financial transparency from big lenders; and improving insurance programs for entrepreneurs. Finally, in terms of public investment decisions, governments can develop and clarify frameworks for inclusive investment, demonstrating a willingness to directly support national industry by purchasing equity in their nation's firms.[25]

While many AI strategies focus on developing competitive advantages in AI itself, they should also look to capitalize on pre-existing competitive advantages (e.g., capitalize on AI research in countries that already have strong academic institutions) and develop AI to support industrial competitive advantages (e.g., supporting the implementation of AI in automobile manufacturing in countries that export cars). In some cases, this may mean the development of a regional focus or "clusters."

The Role of IP

IP commercialization, ownership, and retention are important metrics for innovation success. They signal what percentage of Canadian inventions go to market and succeed in generating revenue for the Canadian economy. One measure of success for the Canadian AI ecosystem is Canadian innovators both creating, owning, and further commercializing and scaling their IP. A 2018 report by the Council of Canadian Academies highlighted that early-stage Canadian innovators often face challenges on this front, causing many to sell their IP rather than leverage it to scale up and commercialize new products and processes.

ICTC research shows that currently, being acquired or bought out is a common form of "exit" for Canadian AI startups. Among a sample of 209 Canadian AI startups that have exited, approximately 50% were either acquired or bought out by another company.[26] Of these, just under 60% were purchased by a foreign entity. The second most common form of exit was going out of business (24%), followed closely by going public (19%). [27] By the same token, a 2019 report by the World Intellectual Property Office (WIPO) identified Canada as having the third-highest number of acquired AI companies, ahead

of AI-economic-powerhouses like Israel, Germany, France, and India.[28]

Stakeholders that ICTC consulted with in the innovation ecosystem have expressed some degree of concern that lower levels of IP ownership and retention could mean less long-term benefits for the Canadian economy. Although early-stage IP sales can also be used by businesses to fund future R&D projects, selling early-stage IP may lead to foregoing late-stage IP, and seeing smaller returns in employment or productivity.[29]

Helping Canadian AI Startups Scaleup

Access to Growth Capital

With a domestic population of just 38 million, Canadian companies need to be export-driven and reach global markets in order to scale successfully (however, this trend varies by industry). These endeavors require growth capital (e.g., venture capital and angel investment, incubator funding, private equity, and commercial bank loans), yet Canadian SMEs regularly report challenges in accessing this form of financing. For example, a 2020 report by ISED looks at access to capital for Canadian growth-oriented, medium-sized firms. The authors determine that there is a three-tier growth capital financing market in Canada:

- Tier One: investors that typically seek deals above the $20-million-mark;
- Tier Two: investors that typically invest around the $10-million-dollar mark; and
- Tier Three: investors that typically invest between $2 and 5 million per deal.[30]

The report finds that while Tier Two contains a broad range of Canadian investors, Tier One predominately consists of US Funds and in Tier Three, "demand for growth capital continues to outpace available supply."[31] One interviewee in the ISED study summarized these challenges as follows:

> *Not too many firms or funds are feeding the capital needs of companies that are too small to attract the interest of the U.S. majors, too low growth to attract venture capitalists, too small for traditional private equity funds and banks…. If you have under $5 million of earnings before interest, taxes, depreciation and amortization and you're growing at 5–10 percent above the consumer price index, then there are few places to turn to….[32]*

Building on the challenge of accessing growth capital, a 2018 study on growth capital by the University of Toronto Impact Centre compares 983 companies from five countries that were founded in 2008. According to the study, in comparison with US companies, Canadian companies also take longer to obtain their first round of financing, go through fewer rounds of financing in total, and "raise significantly less money before exiting."[33] The authors conclude that for Canada to create more world-class companies, Canadian tech companies will "need to get funding sooner and in larger amounts to be able to drive growth."[34]

Another possible way to help Canadian AI startups scale is prioritizing public procurement. Procurement opportunities represent an income stream for Canadian start-ups, while also providing them with an opportunity to test, refine, and further scale their products and services in a given market. Success via this route simultaneously increases the business' ability to obtain further private-sector funding. Although many programs already exist to encourage public procurement (such as the Government of Canada's list of approved AI suppliers[35]) it remains to be seen what percentage of contracts will be awarded to Canadian SMEs.[36]

Strategic International Partnerships

Canada is a relatively small economy, making international partnerships a fundamental pillar of Canadian economic activity. Foreign investors account for a significant portion of Canada's private-sector funding and foreign companies are key partners in Canadian academic research. In addition, Canadian subsidiaries of foreign companies can provide high-paying and highly skilled work opportunities, increased innovation capacity, and other positive spillover effects. On the flipside, with its highly skilled workforce, generous tax credits, and R&D support, Canada is a valuable partner to foreign companies. Nonetheless, R&D programs constitute a co-investment on the part of the government (and the public) with companies and academic researchers: in the digital economy where IP and data are so highly valued, realizing the full benefit of this co-investment means also securing commercial IP rights for Canadian companies and inventors.

Securing IP Rights in Academic Partnerships

Academic research programs like NSERC and the Canada Research Chairs rely on partner institutions' resident IP policies. This means that post-secondary institutions' IP policies impact the outcome of this IP, yet Canada's academic landscape consists of widely varied approaches.

Post-secondary institutions are often responsible for establishing their own individual IP policies and technology transfer offices (TTOs), and while some institutions adhere to "institution-owned" IP policies, others follow "inventor-owned" or "hybrid" policies.[37] Likewise, some TTOs (and researchers for that matter) may be better resourced or more familiar with the intricate details of IP and are therefore better equipped to negotiate IP contracts.[38] That said, not all academic researchers are willing or able to bring an invention to market; this is an undertaking that requires significant time, energy, and financial resources, alongside entrepreneurial spirit and expertise. Regarding the latter, re-aligning individual incentive systems with larger ecosystem needs (for example, the incentive systems that drive IP decision making by academic researchers, TTOs, CEOs, and founders) may be key in generating rich IP spun off from academic institutions.

The Government of Ontario assembled an Expert Panel on Intellectual Property in Spring 2019 to assess the scope of these challenges in Ontario. One of the Panel's key recommendations was to establish "a centralized provincial resource to provide consistent, sophisticated legal and IP expertise and education."[39] The recommendation would bring Ontario closer in line with Québec[40] and other innovation economies globally[41] by establishing a centralized resource for IP and commercialization expertise. In Germany, the quasi-public Fraunhofer-Gesellschaft goes one step further to govern commercial research exploitation: its 74 research institutes work closely with more than 180 German universities and industry partners on seven strategic research areas, including AI, next generation computing, and quantum technologies.[42] Fraunhofer's standard IP agreement is that, so long as a researcher uses Fraunhofer resources, Fraunhofer will own the IP. For more complex partnerships, Fraunhofer will identify each party's contribution and ensure "equivalent royalty payments upon successful commercialization."[43] These strategic IP agreements help enable the Fraunhofer to generate a three-fold return for the public purse.[44]

Securing IP Rights in Industry

While many factors influence IP rights, one commonly discussed factor is IP literacy. A survey conducted by Statistics Canada found that, "of the businesses that registered IP in Canada, the main obstacles encountered were the complexity of the procedure (56.3%)."[45] Another survey conducted by EUIPO identified "lack of knowledge" as the most common reason for not registering IP.[46] IP is a business tool and Canadian entrepreneurs must be able to make informed decisions about their IP. Organizations like the Canadian Intellectual Property Office (CIPO) have begun work on this front[47] but there are countless other venues where it can continue—for example, in computer

engineering programs or other post-secondary programs related to ICT, and at industry events like conferences, trade shows, and hackathons.

A second factor in IP ownership and retention is the cost of IP legal advice or enforcement.[48] Budget 2021 proposes funding for two new initiatives on this front to overcome this hurdle, including $90 million to help accelerators and incubators provide startups with access to expert IP services; and $70 million for the NRC to provide high-growth client firms with IP services.[49] The Digital Technology Supercluster also already had within its mandate a responsibility to "work with Members to help ensure that investments in innovation are protected," and "at its discretion, support the cost of obtaining IP protection in cases of demonstrated need."[50] Going forward, it will be beneficial to continue to develop and trial new initiatives related to IP advice.

Legal Instruments to Support Digital Adoption

In Canada, data mobility provisions are not currently well represented in federal privacy law.[51] In the financial services sector, this has prevented direct API (Application Programming Interface, a software intermediary that allows two applications to talk to each other.), access to commercial banks' customer data, in turn stalling large scale adoption in the field of Open Banking.[52] In other sectors, it poses challenges for customers to easily port their personal data from one product or service provider to another (which also impacts competition). Lastly, data use in Canada is currently dampened by outdated copyright law, limiting which datasets can be used to build, test, and train AI in commercial settings: other jurisdictions have amended their laws in recent years to account for this challenge.[53]

Digital Infrastructure to Support Digital Acceleration

A second part of the digital infrastructure needed for a successful AI industry is telecommunications infrastructure and advanced computing resources. The need for affordable and accessible telecommunications infrastructure, including broadband infrastructure, data storage and processing centres, in Canada is growing, a trend heightened by increased digitization amid the pandemic.[54] Additionally, affordable computing power is also essential for start-ups, SMEs, and other organizations from civil society and the not-for-profit sector.[55] Access to affordable advanced computing resources and high quality connectivity is a critical component of an equitable national AI strategy that fosters inclusive growth.

Section II: The Demand for AI Talent and Skills for Success

AI researchers and PhDs form critical foundation blocks for digital innovation and adoption. However, alone, they are not enough to build an economically vibrant AI sector for Canada: quality, refined data is required to fuel the deep learning and machine learning algorithms for globally competitive AI products to be made, and skilled talent is critical to commercialize and scale them. The role of data engineer has emerged as central to AI product development, alongside traditional AI enabling roles like data scientists and data analysts. However, AI and data-centric roles themselves cannot exist in a purified research vacuum; these professionals need to have domain knowledge (pertaining to the sector where the AI is applied) and strong interpersonal skills to work in multidisciplinary product teams.

In-Demand AI Skills

A globally competitive AI ecosystem requires both direct skills (designing, building, delivering AI models and systems) and indirect skills (oversight, ethics, privacy, legal, audits). For the direct skills, Monica Rogati's *AI Hierarchy of Needs* provides a framework to gauge AI skill demands (see Figure 2).

The Data Science Hierarchy of Needs

learn/optimize
aggregate/label
explore/transform
move/store
collect

AI, deep learning

A/B testing, experimentation, simple ML algorithms

analytics, metrics, segments, aggregates, features, training data

cleaning, anomaly detection, PREP

reliable data flow, infrastructure, pipelines, ETL, structured and unstructured data storage

instrumentation, logging, sensors, external data, user generated content

Figure 2. More job opportunities exist towards the lower layers of the pyramid, while the upper layers are highly specialized and provide a lower volume of job opportunities. Source: Monica Rogati, 2017

Starting at the base of the pyramid, which relates to data collection, the skills required are in the sphere of industrial instrumentation and sensors, third-party data acquisition, and web and mobile-based application design. Moving upwards, the "move/store" and "explore/transform" layers represent the domain of the data engineer: turning raw, multi-sourced data into consumable data for data analysts, data scientists, and AI professionals. Finally, machine learning engineers, AI architects, and data scientists are situated in the top layer of the pyramid. While there are more opportunities towards the lower layers of the pyramid, the upper components are highly specialized and therefore not a volume-based opportunity for people looking to AI as a career choice.

As is seen in *Table 1*, the skills associated with the jobs of data engineer, data analyst, data scientist, ML engineer, and AI architect do overlap but there are clear distinctions as well.

Role	Skills
Data Engineer	SQL, C++, Tableau, Jenkins, Python, GitHub, Extract Transform Load (ETL)
Data Analyst	Excel, Data Management, Mathematics, SQL, MS Access, Visualizations, Tableau
Data Scientist	Excel, SQL, ML, AI, Text Mining, Python, Tensorflow
AI Architect	ML, Big Data, SQL, Java, C++, Python, Deep Learning
ML Engineer	Algorithms, Deep Learning, Computer Vision, Natural Language Processing (NLP), Java, C++, Python

Table 1. Some skills overlap, but there are clear distinctions as well. The relative importance of skills will change over time as some tools drop out of use and others emerge and evolve at an accelerated rate. ICTC analysis of job postings, 2020-2021

More difficult to define, but no less important, are the indirect skills related to ethical AI oversight and responsible AI operations. AI ethics and oversight is more than an operational issue and needs to be a strategic imperative. For example, boards of directors need to take responsibility and set up AI oversight frameworks.[56] To that end, the Institute of Corporate Directors offers a course to its members on Board Oversight of AI to help corporate directors understand the risks and their responsibility regarding AI.[57] Likewise, an interdisciplinary strategy involving ethicists, social scientists, ethnographers, lawyers, auditing professionals, insurance professionals, and more will be needed to ensure responsible and safe use of AI. This includes incorporating industry standards into audits and AI systems certifications— an increasing trend that needs to continue.

AI has the potential to revolutionize entire sectors in ways that no technology previously has done. However, in so doing, important variables like inclusion and accountability must be being prioritized. When new technologies and AI systems hinder, rather than improve lives, they should not be advanced. This frame requires a non-techno-deterministic approach to building AI; one that removes inevitability. For example, some AI systems should not be built or procured, because they are technically faulty and have caused too much economic and social harm, namely to marginalized groups (e.g., emotion recognition, facial recognition).

Building Domestic AI Talent Pipeline: International Best Practices

In addition to focusing on attracting international talent, building a domestic talent pipeline can make Canada's AI talent strategy more resilient. Canada requires university, college and private sector programs that develop the AI talent needed for 2021 and beyond. In a March 2021 report, *Building Canada's Future AI Workforce*, ICTC identified the importance of multi-disciplinary teams as core to commercial AI success. In addition to general AI talent, it is important to source AI talent in the context of the broader digital economy, integrated into specific domain and business imperatives.[58]

> *Canada's strategy for AI skills development should include cross-training as a fundamental pillar in workforce development efforts. For example, government actors could include acute skill needs (such as the need for multidisciplinary cross training on AI teams) in future plans and programs stemming from the Workforce Development Agreements. Canadian academic institutions should assess the availability (and accessibility) of AI-related courses in non-technical programs such as business, finance, or medical programs; and the availability of domain-specific courses in technical programs like data science or computer engineering. — ICTC, Building Canada's Future AI Workforce[59]*

Domain Expert
Deep expertise in domain, and some knowledge of possible technological approaches for implementation.

Business Expert
Extensive market knowledge, sufficient knowledge in domain and technology to understand market & plausibility of product.

AI/Systems Expert
Expertise in technology, with sufficient knowledge of domain to accurately develop AI model.

Figure 3: Technical nucleus of an AI/ML product development group, ICTC, "Building Canada's Future AI Workforce. Source: Hamoni, R. et al., 2021

Singapore is one country that has attempted to bridge this gap by building multidisciplinary training programs like AI for Industry (AI4I)® and AI Apprenticeship Programme (AIAP)®. Singapore's apprenticeship program (for Singaporeans only) is an intensive 9-month full-time structured program (12 months for people aged 40 and above), including a monthly stipend and 7 months on-the-job training. [60] The AI4I program offers free and premium AI training modules for professionals.[61] Singapore is executing on a plan to develop a world-class AI-ready workforce. Under the specter of the COVID pandemic, remote work and learning have become mainstream, and Canadians need access to skills that will enable them to adapt and thrive.
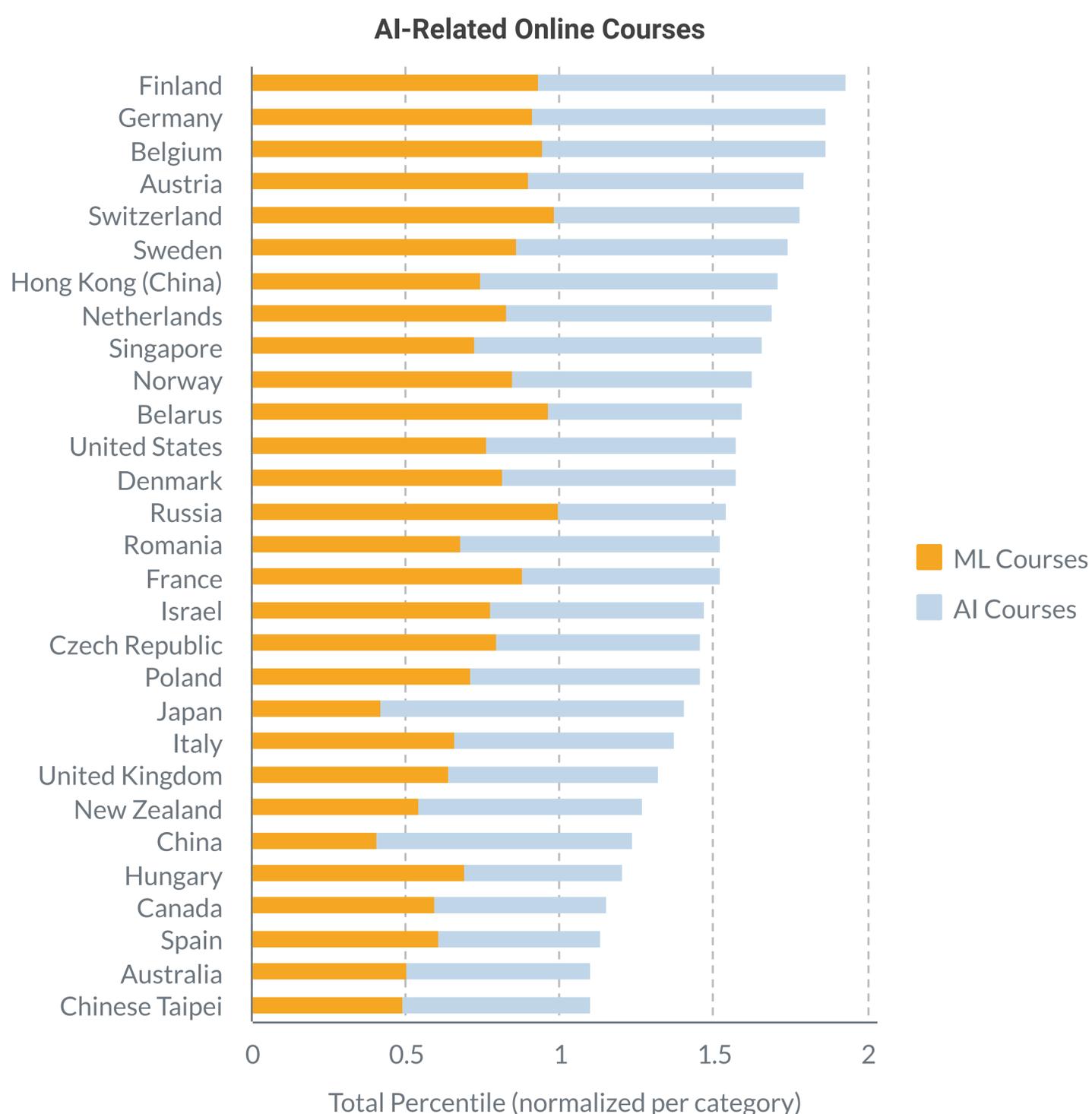
Figure 4. AI-related Online Courses, 2019: Top 30 countries. Data source: "Cross-Country AI Skills Penetration," 2021, OECD.AI Policy Observatory, https://oecd.ai/data-from-partners?selectedTab=AIJobsAndSkills

Sourcing Talent: Developing a Competitive Landscape

Attracting and Retaining AI Talent: The International Playing Field

Building the Canadian AI talent pipeline will involve both developing domestic talent and attracting and retaining international AI practitioners. Canada's Budget 2021 acknowledged this dual pipeline, and provides funding for securing academic talent across the country via $162 million over ten years to be delivered by the Canadian Institute for Advanced Research.

Figure 5 illustrates Canada's AI skills strengths when compared to other countries on a relative population basis. Although Canada is currently a global leader in this space, it is imperative to identify new and evolving competitive practices to attract and retain internationally trained AI talent. [62]

Cross-Country AI Skills Penetration
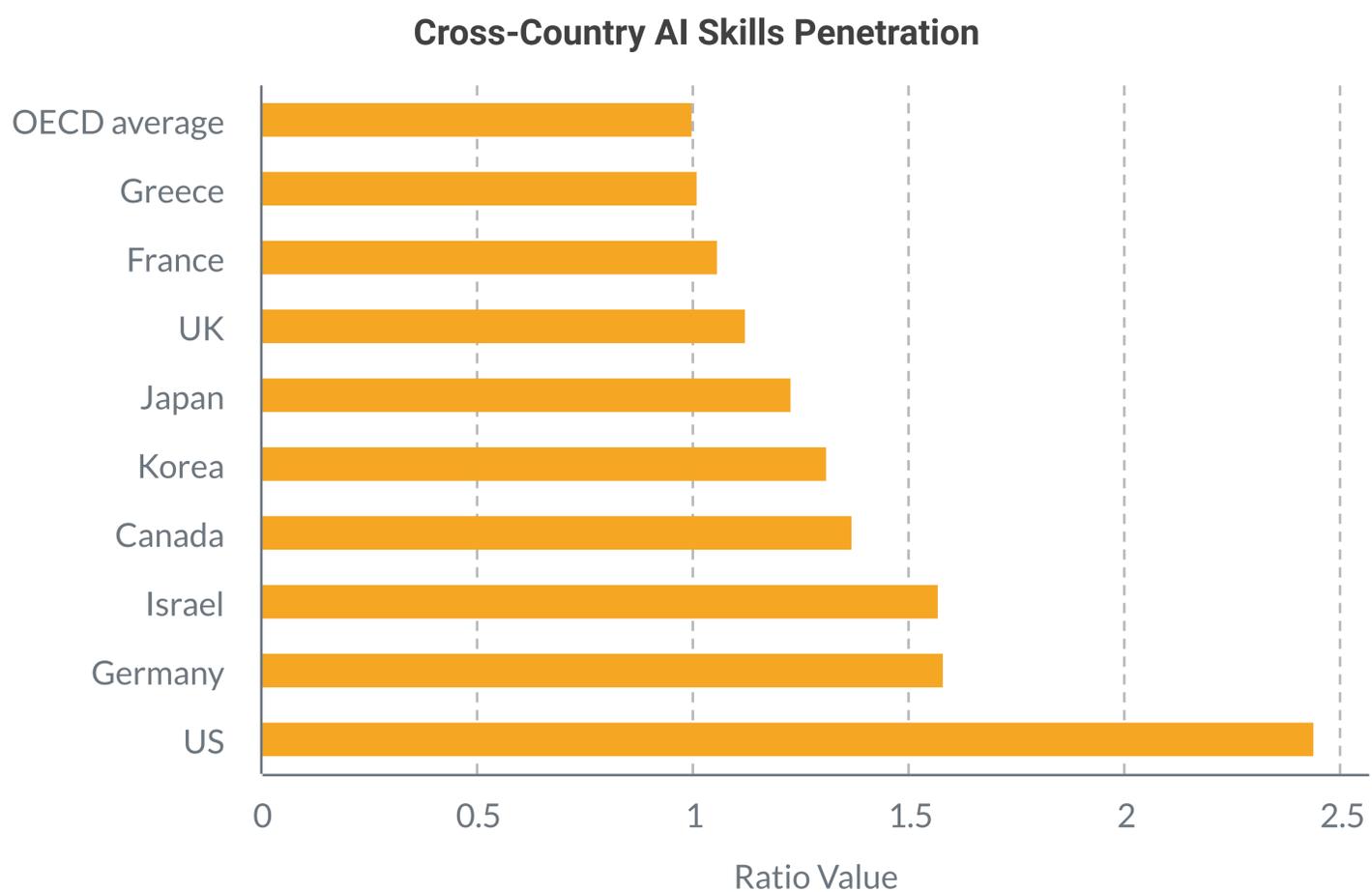
Figure 5. Cross-Country AI Skills Penetration: top ten countries. Note: Average from 2015 to 2020 for a selection of countries with 100 000 LinkedIn members or more. The value represents the ratio between a country's and the benchmark's AI skills penetrations, controlling for occupations. Data downloads provide a snapshot in time. Caution is advised when comparing different versions of the data, as the AI-related concepts identified by the machine learning algorithm may evolve in time. Please see methodological note for more information. Data source: "Cross-Country AI Skills Penetration," 2021, OECD.AI Policy Observatory, https://oecd.ai/data-from-partners?selectedTab=AIJobsAndSkills

Competitive salaries for AI talent is a key metric for Canadian businesses and governments to be cognizant of. Although competitive with many international jurisdictions, Figure 6 highlights a significant salary gap between Canada and the United States for in-demand AI talent.

Machine Learning Engineer Annual Salary (2021)
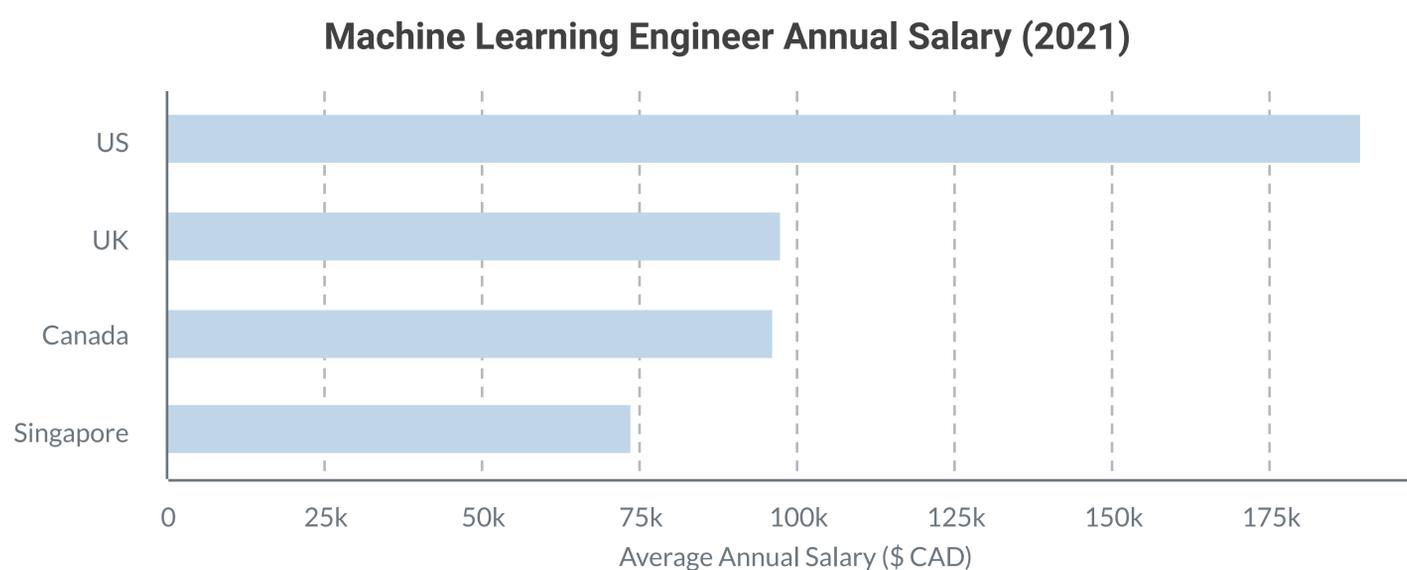
Figure 6. Machine Learning Engineer Annual Salary data retrieved from Indeed.com, accessed June 20, 2021

Canada is still a popular destination for in-bound AI talent location but to maintain that status, it must stay vigilant. Competitive wages are top if mind for skilled international workers when planning to relocate from their home countries. Numerous initiatives can help with the wage calculus and attract top AI talent, and many such programs have been piloted around the world. In the case of the Netherlands, the 30% rule enables expat employees (who meet eligibility criteria, including possessing skills that are in short supply) to be exempt from income tax on up to 30% of their salary. Even though the duration of the program has been reduced from 8 years to 5 years, it plays a significant role in attracting skilled international workers.[63] In eastern Europe, burgeoning tech hub Romania currently offers a special tax regime for some tech workers, whereby their entire salary is exempt from taxes. Although somewhat extreme (and currently being revisited), the measure has been largely successful, attracting skilled workers and scaling the country's ICT sector, which is now responsible for 6% of its GDP.[64]

Cross-Country AI Skills Penetration
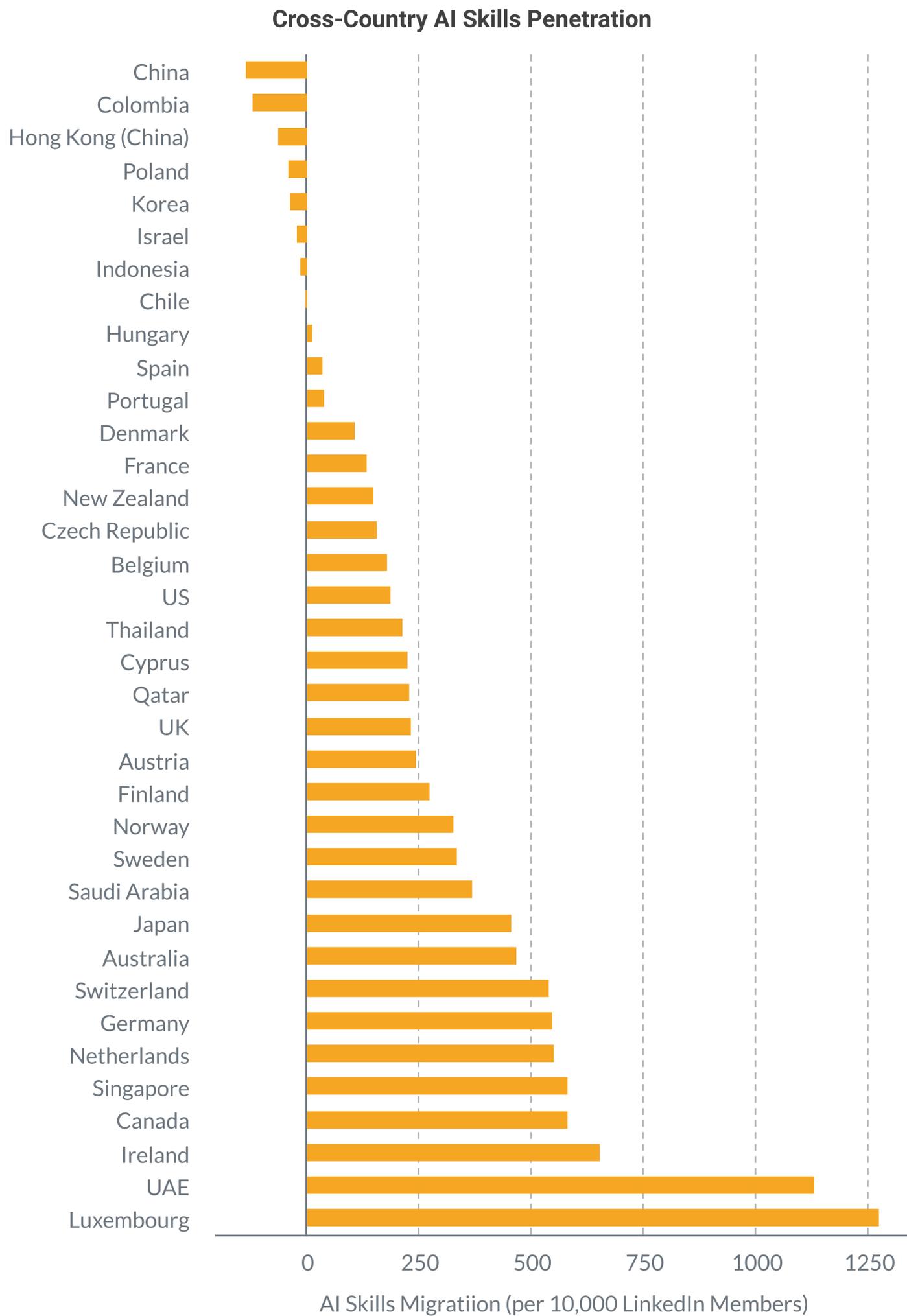
Figure 7. Between-country AI Skills Migration 2019. Data source: "Cross-Country AI Skills Penetration," 2021, OECD.AI Policy Observatory, https://oecd.ai/data-from-partners?selectedTab=AIJobsAndSkills

Section III: Responsible AI Innovation

Renewed investment in the Pan-Canadian AI Strategy—with specific funding earmarked for commercialization—presents a unique opportunity to drive responsible AI innovation in the private sector.

Beyond legislation, there are at least three things that can be done to help clarify approaches to responsible AI governance. First, is a unified approach to AI governance, through a Responsible AI framework that includes a series of principles as well as model governance frameworks for both the public and private sectors. Second, is a comprehensive study to help foster enhanced understanding of the risks and harms posed by the misuse of AI, as well as regulatory solutions to support public accountability. Third, there must be enhanced clarity on how the responsible AI principles may be applied to standardization efforts and innovation programs to drive inclusive innovation and sustainable growth.

A Model Governance Framework for Canadian AI

At a high level, the Government of Canada can spearhead significant leadership on responsible AI governance by synthesizing the work done through the Pan-Canadian AI Strategy and other AI policies and programs into a consolidated Responsible AI framework. Existing initiatives under TBS, such the Guiding Principles for Responsible AI, Directive on Automated Decision-Making, and the Algorithmic Impact Assessment, have laid the foundations for this work. Further leadership will be key in safeguarding the public from harmful uses of AI and, in turn, to accelerate the adoption of its beneficial applications.[65]

Increasingly, companies view robust AI governance as a prerequisite to large scale deployment.[66]Countries such as Singapore have already developed their own model AI governance frameworks and others are expected to follow suit. Recently, for instance, the US National Security Commission on AI recommended that the United States establish a task force to develop a model of "democratic AI governance". The European Commission (EC), having already developed the *Ethics Guidelines for Trustworthy AI*, released its proposal for a regulation laying down harmonized rules on AI, creating the European Union's (and the world's) first ever legal framework on AI.[67] The EC's proposal adopts a risk-based approach to regulating AI, containing obligations for

for providers and users of high-risk AI systems (e.g., quality management and conformity assessments), as well as prohibitions for certain harmful AI applications.[68] On data, the EC proposal recommends requiring datasheets for high-risk AI (something Canada should consider in an AI governance framework), alongside other measures like AI regulatory sandboxes.

Through international engagement at the UN, OECD, and G7, and through its work co-founding the values-based Global Partnership on AI and active participation in the Freedom Online Coalition, Canada has also established a reputation as a global leader on responsible AI. The next iteration of Canada's National AI Strategy should synthesize Canada's domestic and international policy positions into a single, model AI governance framework, and a supporting toolkit. Among other things, this framework can include a series of AI principles and guidance material regarding the roles and responsibilities of AI actors; a model risk assessment; and harm-prevention regulatory measures. Such a consolidated framework can be a significant enabling factor for AI progress and commercialization in Canada, while fostering a harmonized approach to AI governance across government.[69]

Modern Privacy Legislation

While over-regulation can have negative impacts on innovation, particularly for SMEs, the adoption of appropriate, proportionate policy instruments and guidance can help remove barriers to growth, foster trust, and introduce clear normative and technical standards. In other words, appropriate regulation can foster innovation. A recent study conducted by KPMG noted that, particularly as AI adoption has accelerated over the course of the pandemic, business leaders are increasingly conscious that controls are needed and overwhelmingly believe the government has a role to play in regulating AI technology.[70] Today, in addition to general common law principles, instruments such as the Charter of Rights and Freedoms and the Personal Information Protection and Electronic Documents Act (PIPEDA) are among the only legal tools available to govern AI in Canada—critically, these tools pre-date modern AI.

In addition to promoting data ethics and clarifying data privacy rules, modern privacy legislation could enable innovative and inclusive data sharing models, such as data cooperatives, data commons, data trusts, and data fiduciaries.[71] In 2020, the federal government introduced Bill C-11 and the Quebec government introduced Bill 64: if passed, both would establish new legal tools to govern AI in their respective jurisdictions.[72]

Industry Standards and Governance Tools

From biased algorithms used in credit scoring or hiring, to the use of mass surveillance technologies such as facial recognition, to the spread of online hate and disinformation, certain applications of AI are already causing harm in society. In many cases, the human rights, health and financial well-being of society's most vulnerable communities are disproportionately affected by AI applications.[73] Therefore, building trust in AI technologies may take time. Industry standards and governance tools will help build trust and provide regulators with a platform to create and evolve the necessary AI harm protection as well as guidance for companies on risk mitigation, policies and procedures.

Industry standards were a key component of this year's federal budget. Budget 2021 earmarks $8.6 million under the second iteration of the Pan-Canadian AI Strategy "to advance the development and adoption of standards related to AI," and proposes "to provide $8.4 million over five years, starting in 2021-22, and $2.3 million ongoing, to the Standards Council of Canada to continue its work to advance industry-wide data governance standards."[74]

Industry standards and conformity assessments play a dual role in driving innovation and good governance in the digital economy. Companies, particularly SMEs, benefit from clear guidelines on best practices for their own internal data governance and analytics practices: just as common, adaptable frameworks can facilitate collaborations between firms and scale commercialization. Policy makers also rely increasingly on standards as agile regulatory instruments that can keep pace with innovation, companies' evolving data practices and societal expectations. Performance standards for AI models, which can help assess potential for bias, fairness and accuracy, will ultimately play a significant role in ensuring both the quality of AI systems developed but also the prevention of harm.[75] As normative and technical standards mature, governments can introduce audits as part of ongoing regulatory oversight, and requirements for companies to proactively demonstrate compliance through appropriate practices and policies.

AI has had an increasingly profound impact on global trade vis-a-vis data flows and trade commitments. Likewise, AI development and distribution is increasingly supported by international trade agreements like the Comprehensive and Progressive Agreement for Trans-Pacific Partnership and United States-Mexico-Canada Agreement.[76] The Digital Economy Partnership Agreement (DEPA) entered into between Singapore, New

Zealand and Chile, which Canada is currently exploring joining, contains non-binding modules that recognize the "economic and social importance of developing ethical and governance frameworks for the trusted, safe and responsible use of AI technologies" and commit the parties to promoting the "adoption of ethical and governance frameworks that support the trusted, safe and responsible use of AI technologies in internationally recognized principles or guidelines, including explainability, transparency, fairness and human-centred values". Internationally recognized standards for data and AI, through their reference in trade agreements or adoption in large-scale digital infrastructure development projects, will play a critical role in determining which AI systems are disseminated globally. Therefore, standards need to be developed with a global context in mind.

Through the work of the Data Governance Standardization Collaborative (DGSC), a multi-stakeholder group of experts from the public service, industry, academia and civil society, the Standards Council of Canada (SCC) has helped drive progress towards creating a roadmap of priority AI standards and conformity assessments that should be developed as matter of priority. The DGSC's work is expected to set the stage for future standard development in other emerging areas, such as AI and big data analytics, and promote future compliance efforts with emerging AI regulations. Given the increased commercial and regulatory demands for data and AI standards, new policies and resources may be necessary to help ensure the standardization ecosystem is equipped to meet rising demand. Developing strong industry standards for AI should entail:

- **Facilitating further SME participation in standardization activities:** Launched in April 2018, the Innovation Program enables the SCC to help Canadian innovators develop tailored standardization strategies, and provides financial support to fund some of the associated costs. SCC recently reported that the program is on track to deliver 63 strategies by 2022 and that approximately 60% of the companies engaged have already reported an increase in either exports, jobs or revenue as a direct result of the program. Parallel funding can be provided to enable members of academia, civil society and equity-seeking groups to participate in standardization activities.
- **Enhancing the capacity and efficiency of the AI standards development process, and subject matter experts with expertise in various areas, and a diverse steering committee:** The output of the DGSC has benefited greatly from the active participation of representatives from SCC, Statistics Canada, and ISED. Sustained multi-stakeholder engagement can help to ensure that data and AI standards identified by the DGSC are developed in a timely manner and in accordance with legislative objectives.
- **Identifying new ways to comprehensively assess and certify AI systems:** For instance, these may include the development of regulatory technologies for AI governance that aim to provide scalable assessment and certification schemes for AI systems based on

the latest industry standards and best practices. Innovative Solutions Canada's streams could be leveraged to fund the development and testing of prototype solutions for public sector AI deployment. These systems will also require open and independent oversight by public-facing subject matter experts. Other innovations programs, such as the Superclusters, could be adapted to include a governance stream, which would support the development of AI governance solutions and tools for the private sector.

Inclusive Indicators for Innovation Success

IP retention and commercialization are important metrics for innovation success because they signal what portion of Canadian inventions may go to market. IP assets are increasingly centre stage in company valuations, and intangible assets account for 90% of the total value of tech giants like Microsoft and Amazon, and 84% of the value of the top S&P 500 companies.[77] Despite this, indicators used to assess Canada's AI R&D programs do not account for domestic IP ownership. The most recent assessment report for the Pan-Canadian AI Strategy highlights foreign acquisition of Canadian IP as a *positive* indicator for ecosystem success,[78] while programs like the Superclusters Initiative and SIF use metrics like job and GDP growth[79] to measure innovation. Although relevant, additional metrics are necessary to paint a holistic picture and support commercialization. A recent report by the Parliamentary Budget Officer (PBO) notes that apart from GDP and job growth, the Superclusters Initiative lacks "quantifiable performance indicators" for measuring the program impact on innovation.[80]

Examples of commercialization-focused indicators—such as those used by the ECSEL Joint Undertaking and other publicly funded R&D programs in Europe—include the number of resulting patents, publications, and prototypes, the number of associated clinical trials, and the number of companies introducing new innovations either within their company or to market.[81] Further possible indicators, this time suggested by the Council of Canadian Academies, are the number of invention disclosures, licensing deals and income, and spin-off companies associated with specific funding programs.[82]

In addition to indicators for IP commercialization, retention, and ownership, it is important to establish indicators for inclusive economic growth. Choosing the right indicators is an important part of program and policy development: indicators embody a program's concrete goals and define not only what success looks like, but to whose benefit the program exists. Metrics like GDP growth, funding commitments, and job growth represent too narrow an approach.[83] Moving forward, industrial policy needs to centre on a more inclusive understanding of economic growth: "we need to look beyond

GDP and job growth to understand whether the economy is working for everyone," and "pay better attention to sustainability, wealth inequality, and well-being."[1] Similarly, using tools like "socio-economic impact assessments," governments can undertake more comprehensive impact assessments of the AI technologies they procure or produce.[2]

Opportunities for Future Success

Canada has invested significantly in AI R&D, and Budget 2021 represents a willingness to double down. With significant new investments in AI on the table, now is the right time to strengthen Canada's industrial strategy for AI and develop the components for future growth and success. To build an industrial AI strategy for Canada, ICTC proposes the following recommendations:

Establishing a clear industrial strategy for AI

Strategy Development: A clear industrial strategy for AI can align Canada's existing AI programs so that they are well-coordinated across government departments and complement one another effectively. For example, a centralized unit that is responsible for AI policy planning and delivery could be established within government (see footnote for more details).[1] This unit could help ensure that public investments in AI yield the greatest returns (for all of society).

Innovation Supports: New and existing programs should prioritize Canadian IP ownership, retention, and commercialization in program guidelines, eligibility requirements, and success indicators. Programs involving international partnerships should seek to secure a strategic IP position for Canadian SMEs when possible. Relevant organizations should determine and evolve methods to properly incentivize IP commercialization and/or domestic IP ownership and retention (and make necessary adjustments), and develop comprehensive, inclusive indicators for innovation success.

Ensuring the right ingredients for late-stage R&D success

Talent: Canada's industrial strategy for AI should ensure the right ingredients for late-stage R&D success. Building and sourcing both AI (e.g., Data Engineers, AI Architects, ML Engineers) and broad ICT (e.g., Software Developers and Engineers) talent and skills needs is crucial, as is attracting and retaining multidisciplinary talent that understands how to apply AI

across various business domains. Going forward, as Canada competes for world-class AI talent, it will be important to track and implement international best practices for talent attraction and retention.

Regulatory and Digital Infrastructure: Digital Infrastructure is a necessary ingredient for late-stage R&D success in the field of AI. Changes to privacy legislation and other legal infrastructure are necessary to enable data sharing in key industries like healthcare and financial services, as are secure, technical methods for data sharing. In addition, it is critical to support the development of affordable telecommunications infrastructure, including data storage and processing centers, computing infrastructure, and high-speed internet access.

Driving responsible, inclusive growth

Governance: Responsible AI governance is a core party of any industrial AI strategy. By developing governance and industry standards to drive inclusion and accountability, Canada can set itself apart as a global leader in this space.

Enabling Responsible AI: There is an urgent need to establish an inclusive and accountable framework to not only mitigate but prevent harms stemming from technology solutions: the intent is to be proactive about harm reduction (e.g., not just risk averse, but harm averse). New regulation is needed to guide inclusive, accountable, and responsible AI in government and industry (for example, by translating the principles of the Digital Charter into privacy legislation).

Conclusion

Strong research communities, expert talent, and a diverse ecosystem of start-ups are just some of Canada's strengths in the field of AI. Capitalizing on these strengths will require a clear and coordinated industrial strategy for AI, that not only builds on the existing Pan-Canadian AI Strategy, but further prioritizes IP ownership and commercialization, AI talent, and responsible AI. Budget 2021 started this process, earmarking up to $443.8 million over ten years to renew the Strategy and make other significant investments in R&D programs related to AI. This paper provides additional research and insight as to what else is needed to achieve this goal.

Section I of this paper explained the economic imperative for commercialization AI research. Industry adoption and late-stage, commercial R&D will be needed to capitalize on existing investments in this space. The second half of **Section I** discussed the groundwork needed for AI commercialization. Canadian IP ownership and retention were identified as natural precursors to Canadian companies commercializing AI research. Interventions like providing affordable IP advice or centralized IP education resources are examples of novel approaches to support homegrown IP development and commercialization. Finally, **Section I** discussed the digital infrastructure needed for a successful AI industry, including legal and technical infrastructure for data sharing and affordable broadband infrastructure, data storage and processing centres, and high-performance computing resources.

Section II focused in on current and future demand for AI skills and talent in Canada. Direct skills related to designing, building, delivering AI models and systems, and indirect skills related to ethics and legal oversight were identified as being important for a globally competitive AI ecosystem. Similarly, five technical roles (e.g., Data Engineer, Data Analyst, Data Scientist, AI Architect, and ML Engineer) and their core skillsets were defined. Finally, drawing from past ICTC research, the need for multidisciplinary talent that understands how to apply AI in various business domains was discussed. The second half of **Section II** introduced a topic inherent to talent in the global economy: establishing Canada as an attractive destination for global AI talent.

Section III focuses on the need for responsible AI governance. First, it outlines the

possibility of synthesizing the work done through the Pan-Canadian AI Strategy and other AI policies and programs into a consolidated Responsible AI framework model governance framework for Canadian AI. Next, **Section III** discusses the imperative for establishing modern privacy legislation, including data ethics and data sharing provisions to bolster a responsible AI industry in Canada. Finally, industry standards, conformity assessments, and other governance tools are also introduced as ways to drive innovation and good governance simultaneously.

End Notes

[1]"A RECOVERY PLAN FOR JOBS, GROWTH, AND RESILIENCE," 2021, *Department of Finance*, https://www.budget.gc.ca/2021/pdf/budget-2021-en-pdf

[2]"A RECOVERY PLAN FOR JOBS, GROWTH, AND RESILIENCE," 2021, *Department of Finance,* https://www.budget.gc.ca/2021/pdf/budget-2021-en.pdf

[3] For example: expanding AI research in Canada, fostering an AI research network, and creating academic research positions. "Pan-Canadian AI Strategy," 2021, *CIFAR,* https://cifar.ca/ai/

[4] "Global AI Strategy Landscape," 2020, *HolonIQ*, https://www.holoniq.com/wp-content/uploads/2020/02/HolonIQ-2020-AI-Strategy-Landscape.pdf; Johnny Kun, Gaga Boskovic, Charlotte Stix, "Building an AI World: second edition," 2020, *CIFAR,* https://cifar.ca/wp-content/uploads/2020/10/building-an-ai-world-second-edition.pdf.

[5] The OECD highlights these tools as being present in digital innovation policy programmes, rather than national AI strategies, but they remain relevant in both. See: "Review of national policy initiatives in support of digital and AI-driven innovation," 2019, *OECD*

[6] Tim Dutton, Brent Barron, Gaga Boskovic, "Building an AI World," 2018, *CIFAR,* https://cifar.ca/wp-content/uploads/2020/05/buildinganaiworld_eng.pdf

[7] "Review of national policy initiatives in support of digital and AI-driven innovation," 2019, *OECD,* https://www.oecd-ilibrary.org/docserver/15491174-en.pdf?expires=1612482024&id=id&accname=guest&checksum=47A2C75087D9C661B2137EA69C3C671E

[8] AI strategies are only one element of AI policy. It is possible for a country to have complex and well-developed AI policy without a dedicated national strategy document, or conversely, a detailed national strategy document, yet underdeveloped policy implementation. In this report, we focus on Canada's AI strategy and accompanying policy.

[9] That said, it is difficult to say for sure which national AI strategies have been most effective—partly because of the multitude of exogenous factors and partly because many strategies were only created very recently.

[10] "A Framework for Developing a National Artificial Intelligence Strategy", World Economic Forum, 2019, http://www3.weforum.org/docs/WEF_National_AI_Strategy.pdf

[11] "A Framework for Developing a National Artificial Intelligence Strategy", World Economic Forum, 2019

[12] "A Framework for Developing a National Artificial Intelligence Strategy", World Economic Forum, 2019

[13] Charles Bradley and Richard Wingfield, "National Artificial Intelligence Strategies and Human Rights: A Review", Stanford Cyber Policy Center, 2020

[14] Matthews, M., Quan, T., and Rice, F., "RESPONSIBLE INNOVATION IN CANADA AND BEYOND Understanding and Improving the Social Impacts of Technology," 2021, ICTC, https://www.ictc-ctic.ca/wp-content/uploads/2021/01/ICTC_Report_SocialImpact_Print.pdf

[15] In 2018, CIFAR announced 29 Canadian AI research chairs. This grew to 80 in 2019, and to 109 in 2021. "Canada's Leadership in AI," 2021, CIFAR, https://cifar.ca/ai/canadas-leadership-in-ai/

[16] These have been centred on three labs: Amii, Mila, and the Vector Institute.

[17] For example, CIFAR convened the AI Health Task Force during the COVID-19 pandemic. "Pan-Canadian AI Strategy," 2021, CIFAR, https://cifar.ca/ai/

[18] CIFAR supports this objective through workshops and policy engagement, reports on AI globally, and a "Solutions Network" to support AI governance. "AI & Society," 2021, CIFAR, https://cifar.ca/ai/ai-society/

[19] CIFAR acknowledges this narrow focus, noting that the Pan-Canadian AI Strategy contains no elements relevant to the domains of the Future of Work, data and digital infrastructure, AI in government, or inclusion. See: Kung., "BUILDING AN AI WORLD: REPORT ON NATIONAL AND REGIONAL AI STRATEGIES SECOND EDITION," May 2020, CIFAR, https://cifar.ca/wp-content/uploads/2020/10/building-an-ai-world-second-edition.pdf

[20] "Advisory Council on Artificial Intelligence," March 8th, 2021, ISED, http://www.ic.gc.ca/eic/site/132.nsf/eng/home

[21] "Commercialization Working Group Final Report February 2020," February 2020, ISED, http://www.ic.gc.ca/eic/site/132.nsf/eng/00011.html

[22] Suggesting at least a partial shift to IP development and commercialization

[23] "Building a Stronger Middle Class: Budget 2017," 2017, Government of Canada https://www.budget.gc.ca/2017/docs/plan/toc-tdm-en.html

[24] Mendelsohn, M. and Zon., "No Country of San Franciscos: An Inclusive Industrial Policy for Canada," Canadian Inclusive Economy Initiative, 2021, https://brookfieldinstitute.ca/wp-content/uploads/No_Country_of_San_Franciscos-1.pdf

[25] Ibid., Mendelsohn, M. and Zon., 2021

[26] Based on a sample of 209 Canadian AI startups that have "exited," meaning they have undergone a qualifying transaction (e.g., M&A, Buyout, IPO/Reverse IPO, Bankruptcy, Out of Business, and Secondary Private Transaction. Dataset compiled using Pitchbook data.

[27] It is possible that the number of startups going out of business is underrepresented due to the added difficulty of accounting for companies that are no longer active.

[28] Qualifying acquisitions took place from 1998 to 2019. See: https://www.wipo.int/edocs/pubdocs/en/wipo_pub_1055.pdf

[29] IP ownership refers to Canadian ownership of IP; while IP inventiveness refers to IP invented by Canadians. See: Gallini, N., and Hollis, A., "To Sell or Scale Up: Canada's Patent

Strategy in a Knowledge Economy," August 2019, IRPP, https://irpp.org/wp-content/uploads/2019/08/To-Sell-Or-Scale-Up-Canadas-Patent-Strategy-in-a-Knowledge-Economy.pdf

[30] Remillard, R. and Scholz, M., "ACCESS TO CAPITAL FOR CANADIAN GROWTH-ORIENTED, MEDIUM-SIZED FIRMS," 2020, *Innovation, Science and Economic Development Canada Small Business Branch,* https://www.ic.gc.ca/eic/site/061.nsf/vwapj/2020_AccesstocapitalforCanadiangrowth.pdf/$file/2020_AccesstocapitalforCanadiangrowth.pdf

[31] Remillard, R. and Scholz, M., "ACCESS TO CAPITAL FOR CANADIAN GROWTH-ORIENTED, MEDIUM-SIZED FIRMS," 2020, *Innovation, Science and Economic Development Canada Small Business Branch,* https://www.ic.gc.ca/eic/site/061.nsf/vwapj/2020_AccesstocapitalforCanadiangrowth.pdf/$file/2020_AccesstocapitalforCanadiangrowth.pdf

[32] Remillard, R. and Scholz, M., "ACCESS TO CAPITAL FOR CANADIAN GROWTH-ORIENTED, MEDIUM-SIZED FIRMS," 2020, *Innovation, Science and Economic Development Canada Small Business Branch,* https://www.ic.gc.ca/eic/site/061.nsf/vwapj/2020_AccesstocapitalforCanadiangrowth.pdf/$file/2020_AccesstocapitalforCanadiangrowth.pdf

[33] "The Class of 2008 Insights from 983 tech companies founded in 5 countries in 2008," May 2018, *University of Toronto Impact Centre,* https://narwhalproject.org/wp-content/uploads/2019/04/The-Class-of-2008.pdf

[34] "The Class of 2008 Insights from 983 tech companies founded in 5 countries in 2008," May 2018, *University of Toronto Impact Centre,* https://narwhalproject.org/wp-content/uploads/2019/04/The-Class-of-2008.pdf

[35] "List of interested Artificial Intelligence (AI) suppliers," 2021, Treasury Board of Canada, https://www.canada.ca/en/government/system/digital-government/digital-government-innovations/responsible-use-ai/list-interested-artificial-intelligence-ai-suppliers.html

[36] Many multinational players have already been pre-qualified as AI suppliers for the federal government: "66% of pre-qualified AI suppliers have headquarters in Canada, and 33% are located abroad." See: Brandusescu, Ana, "Artificial Intelligence Policy and Funding in Canada: Public Investments, Private Interests," *McGill University Center for Interdisciplinary Research on Montreal,* https://www.mcgill.ca/centre-montreal/files/centre-montreal/aipolicyandfunding_report_updated_mar5.pdf

[37] "Intellectual Property in Ontario's Innovation Ecosystem: Expert Panel on Intellectual Property," February 2020, *Queen's Printer for Ontario,* https://www.ontario.ca/document/report-intellectual-property-in-ontarios-innovation-ecosystem

[38] Ibid. *Government of Ontario, 2020*

[39] Ibid. *Government of Ontario, 2020*

[40] "Soutien à la recherche publique - Québec implante un nouveau modèle pour valoriser davantage la recherche publique," July 14, 2020, *Cabinet du ministre de l'Economie et de l'Innovation, Cision,* https://www.newswire.ca/fr/news-releases/soutien-a-la-recherche-publique-quebec-implante-un-nouveau-modele-pour-valoriser-davantage-la-recherche-publique-816977525.html

[41] Including the Fraunhofer-Gesellschaft in Germany, Korean Institute for the Advancement of Technology in South Korea, Israel Tech Transfer Network in Israel, and A*ccelerate, the commercialisation arm of the Agency for Science, Technology and Research (A*STAR) in Singapore.

[42] "Fraunhofer-Gesellschaft," 2021, *Federal Ministry of Education and Research,* https://www.research-in-germany.org/en/research-landscape/research-organisations/fraunhofer-gesellschaft.html

[43] Jewell, C., "Forging the future the Fraunhofer way," April 2017, *WIPO Magazine,* https://www.wipo.int/wipo_magazine/en/2017/02/article_0002.html

[44] Frietsch, R. et al., "CONTRIBUTION TO THE GERMAN INNOVATION SYSTEM – FRAUNHOFER-GESELLSCHAFT," 2018, *Fraunhofer-Gesellschaft,* https://www.fraunhofer.de/content/dam/zv/en/research/Range_of_Services/Fraunhofer-ISI-Impact-Study-Summary.pdf

[45] "Intellectual Property Awareness and Use Survey, 2019," February 18. 2021, *Statistics Canada,* https://www150.statcan.gc.ca/n1/daily-quotidien/210218/dq210218b-eng.htm

[46] "2019 INTELLECTUAL PROPERTY SME SCOREBOARD," 2019, *EUIPO,* https://euipo.europa.eu/tunnel-web/secure/webdav/guest/document_library/observatory/documents/IP_sme_scoreboard_study_2019/executiveSummary/executive_summary_2019_en.pdf

[47] "IP Academy," February 21, 2020, *Canadian Intellectual Property Office,* http://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/h_wr04234.html

[48] "The main reasons cited by respondents who chose not to protect their IP were the financial costs associated with obtaining IP rights (49.0%)." See: "Intellectual Property Awareness and Use Survey, 2019," February 18. 2021, *Statistics Canada,* https://www150.statcan.gc.ca/n1/daily-quotidien/210218/dq210218b-eng.htm

[49] "Budget 2021 A Recovery Plan for Jobs, Growth, and Resilience," 2021, *Government of Canada,* https://www.budget.gc.ca/2021/home-accueil-en.html

[50] "INTELLECTUAL PROPERTY (IP) STRATEGY," April 24, 2019, *Digital Technology Supercluster,* https://www.digitalsupercluster.ca/wp-content/uploads/2019/10/IPStrategy_April242019_Final-1.pdf

[51] Data mobility is a key feature of modern privacy legislation like the General Data Protection Regulation (GDPR) and the California Consumer Privacy Act (CCPA). Bill C-11 proposes to establish data mobility provisions in Canadian privacy law, however the bill has

not yet passed. https://fpf.org/wp-content/uploads/2018/11/GDPR_CCPA_Comparison-Guide.pdf

[52] Open Banking is "the practice of sharing financial information electronically and securely under conditions approved by customers to more easily find products that suit their needs." For example, a commercial bank could share their customer data with a financial technology (fintech) startup. Hamoni, R. and Matthews, M., "Open Banking and Fintech in Canada," 2021, *ICTC*, https://medium.com/digitalthinktankictc/open-banking-and-fintech-in-canada-7519e6809637

[53] For example, the European Union and Japan have implemented "text and data mining" or "informational analysis" exceptions to their copyright laws, while the United States, Israel, South Korea, and Singapore have expanded the scope of their "fair use" provisions. Geist, M., "How Copyright Reform Could Support Canada's Supercluster Investment," March 29, 2019, *CIGI*, https://www.cigionline.org/articles/how-copyright-reform-could-support-canadas-supercluster-investment

[54] "Canada Data Center Market- Investment Analysis and Growth Opportunities 2020-2025," July 2020, *Report Linker*, https://www.reportlinker.com/p05934700/Canada-Data-Center-Market-Investment-Analysis-and-Growth-Opportunities.html

[55] "Digital Research Infrastructure," August 7th, 2019, *ISED*, https://www.ic.gc.ca/eic/site/136.nsf/eng/home; "Home Page," 2021, *New Digital Research Infrastructure Organization*, https://engagedri.ca/; "Commercialization Working Group Final Report February 2020," November 6th, 2020, *ISED*, http://www.ic.gc.ca/eic/site/132.nsf/eng/00011.html

[56] Cory Liepold et al., "Artificial Intelligence and Ethics: An Emerging Area of Board Oversight Responsibility," *The Harvard Law School Forum on Corporate Governance* (blog), June 25, 2020, https://corpgov.law.harvard.edu/2020/06/25/artificial-intelligence-and-ethics-an-emerging-area-of-board-oversight-responsibility/.

[57] Institute of Corporate Directors, "Board Oversight of Artificial Intelligence", https://www.icd.ca/Education/ICD-Courses/Issues-Oversight/Board-Oversight-of-Artificial-Intelligence-AI (accessed on May 1 2021).

[58] Hamoni., R et al., "Building Canada's Future AI Workforce," 2021, *ICTC*

[59] Rosina Hamoni et al., "ICTC_Report_Building_ENG.Pdf," accessed June 20, 2021, https://www.ictc-ctic.ca/wp-content/uploads/2021/03/ICTC_Report_Building_ENG.pdf

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[68] "The placing on the market, putting into service or use of certain AI systems intended to distort human behavior, whereby physical or psychological harms are likely to occur, should be forbidden" See: https://digital-strategy.ec.europa.eu/en/library/proposal-regulation-laying-down-harmonised-rules-artificial-intelligence-artificial-intelligence

[69] e.g., in public sector procurement and deployment, legislative efforts, and the development of industry standards and the design of innovation programs.

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[79] E.g., Job creation and public and private sector funding commitments. http://www.ic.gc.ca/eic/site/125.nsf/eng/00012.html; http://www.ic.gc.ca/eic/site/125.nsf/eng/00022.html;Ibid., Mendelsohn, M. and Zon., 2021

[80] "The Innovation Superclusters Initiative - A Preliminary Analysis, October 2020, *PBO,* https://www.pbo-dpb.gc.ca/web/default/files/Documents/Reports/RP-2021-024-S/RP-2021-024-S_en.pdf

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[83] For example, as of March 6, 2020, the AI Supercluster was estimated by the PBO to have created around 970 jobs, which equates to just under 12 jobs per $1 million in public funding. See: Ibid., PBO, 2020

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https://www.undp.org/content/undp/en/home/librarypage/democratic-governance/anti-corruption/integrating-transparency--accountability-and-anti-corruption-in-.html; "Introduction to Socio-Economic Impact Assessment," 2021, *Review Board*, https://reviewboard.ca/upload/ref_library/SEIA_Guidelines_Chapter_2.pdf

[85] For instance, the UK established the Office for Artificial Intelligence (to provide strategic leadership and momentum across government in delivering its national AI and data strategies) and the Centre for Data Ethics and Innovation (which provides expert advice to the government across sectors on ethical questions). The Government of Singapore established AI Singapore, a national program that formalizes a government-wide partnership comprising the National Research Foundation, Economic Development Board, Infocomm Media Development Authority, SGInnovate, Integrated Health Information System and the Smart Nation and Digital Government Office, an initiative of the Prime Minister's Office. More recently, the White House Office of Science and Technology Policy announced the establishment of the National Artificial Intelligence Initiative Office (which is responsible for overseeing and implementing the United States national AI strategy and will serve as the central hub for federal coordination and collaboration in AI policymaking across the government, as well as with the private sector, academia, and other stakeholders). See: "Centre for Data Ethics and Innovation," 2021, Department for Digital, Culture, Media & Sport, https://www.gov.uk/government/organisations/centre-for-data-ethics-and-innovation; "The White House Launches the National Artificial Intelligence Initiative Office," January 12, 2021, *Office of Science and Technology Policy*, https://trumpwhitehouse.archives.gov/briefings-statements/white-house-launches-national-artificial-intelligence-initiative-office/