

CANADA'S AI ECOSYSTEM

GOVERNMENT INVESTMENT

PROPELS PRIVATE SECTOR GROWTH



UNIVERSITY OF
TORONTO

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INTRODUCTION

As Canadians stayed home to arrest the spread of COVID-19, researchers in university labs, start-ups and hospitals have worked to understand the virus, track its spread, and develop treatments. They've been supported by rapid and substantial government investments in targeted COVID-19 research that aims to solve this global threat.

Canada's AI ecosystem has proven to be an invaluable resource for addressing the pandemic—an integral part of our national immune system. By powering genomic research, tracking and predicting outbreaks, and mining existing and emerging drug and publication data for new insights, AI is helping us manage the pandemic and accelerate the discovery of treatments.

How did Canada build an AI ecosystem that is available to help us through this crisis? The 2017 Pan-Canadian Artificial Intelligence Strategy—which injected \$125 million into the country's top AI talent and research institutions—leveraged decades of support for basic research in machine learning to create the world's first national AI strategy. The Strategy contributed to making Canada one of the leading global players in AI, an important advantage in a sector that will shape the future.

This report summarizes data compiled for the University of Toronto by Global Advantage Consulting Group, a research and analytics firm that provides ecosystem mapping and analysis services to private and public sector clients. Global Advantage's data traces the evolution of the AI ecosystem over the past 10 years and reveals that Canada's dynamic AI private sector has attracted \$3 billion in new investment and created 50,000 jobs at 670 active AI-focused firms across the country. The data also show that Canada has become a powerhouse of AI innovation, producing the most AI patents per million people among G7 nations and China, while Toronto has attracted the densest cluster of AI startups in the world.¹

The pandemic has underlined the vital importance of building a Canadian health-care system and economy that respond to urgent national needs and draw strength from world-class talent and innovative ideas. One lesson from the Pan-Canadian AI Strategy is that strategic government investments that catalyze talent, research and private sector innovation can pave a path out of the pandemic to a more stable and prosperous future.



Pan-Canadian AI Strategy

Delivered by CIFAR, a total of \$125 million funded the following:

- Toronto-based **Vector Institute** received \$44 million
- Montreal-based **Mila** received \$44 million
- Edmonton-based **AMII** received approximately \$28.6 million
- 80 Canada CIFAR AI Chairs across the three AI institutes (\$86.5 million)
- Major research programs include:
 - Learning in Machines & Brains
 - AI & Society

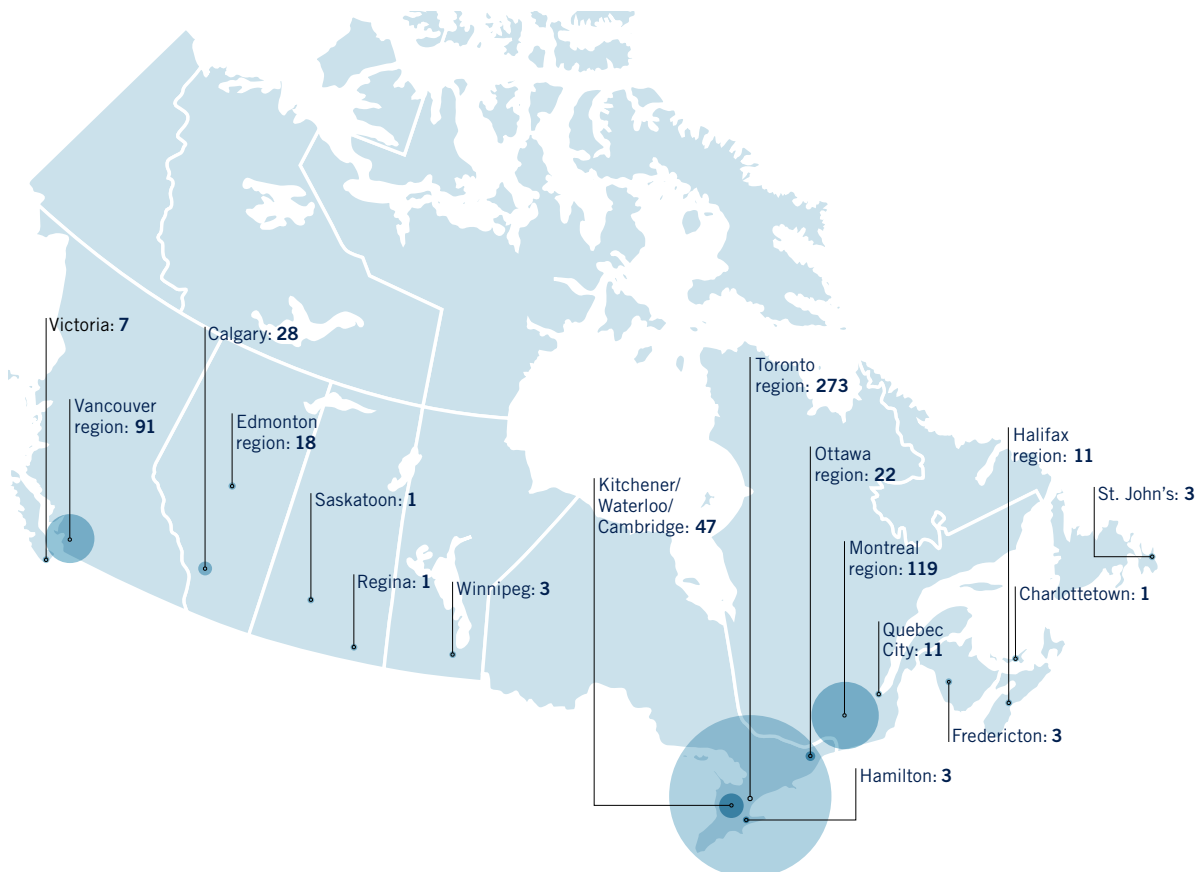
PRIVATE SECTOR GROWTH AND SUCCESS

Over the past decade, artificial intelligence firms have become models of innovation in Canada. According to data compiled by Global Advantage in January 2020, the number of active “pure-play” AI firms (firms with a flagship product or service that implements AI) in Canada has doubled in the past five years to over 660.

Ontario leads overall in the number of pure-play AI firms with 361 companies, compared with 131 in Quebec, 103 in B.C., and 49 in Alberta. Since 2015, these Canadian firms have raised nearly \$3 billion in funding to support AI commercialization.² In addition, 50,000 jobs in AI firms, or requiring AI skills, have been created in

Canada in the past decade, with 26,000 since 2015.³ With 273 AI firms in the GTA, Toronto has the densest cluster of AI startups in the world. The growth in the number of AI companies has coincided with a larger technology boom in Toronto. According to Invest in Ontario, an agency of the provincial government’s Ministry of Economic Development, Job Creation and Trade, Toronto was home to 240,000 technology workers in 2019—a 52 per cent increase in five years—and now ranks ahead of New York City in tech talent.⁴

Major Concentrations of AI Firms by Province



CANADA'S GLOBAL LEADERSHIP

The increase in the number of firms has been accompanied by increases in investment and business initiatives in the AI sector. The Global AI Index,⁵ highlighted in the Global Advantage research, shows that Canada is now ranked fifth overall for commercial AI-focused ventures, a measure that reflects the level of startup activity, investment and business initiatives. And according to the Ontario government, the province has attracted over \$1 billion in investment to its AI sector.⁶

Research and development (R&D) are vital elements of commercialization and engines of national productivity. This level of investment

in AI sets a new standard for Canadian R&D, and demonstrates that smart, targeted policies can potentially reverse the four-decade trend of Canadian firms lagging behind their OECD peers in this area.⁷

Across the 100 weighted indicators that make up the Global AI Index, Canada places even higher at fourth worldwide, trailing only the U.S., China and the U.K.⁸ This is further evidence of the advantage Canada gained by launching a government strategy before other countries adopted similar approaches. According to the OECD, at least 50 countries have developed or are developing national AI strategies.⁹

Global AI Index (Tortoise Intelligence)

	Talent			Infrastructure			Operating Environment			Research			Development			Government Strategy			Commercial			Total Rank
U.S.	1	1	6				1	2		13	1	→	1									
China	18	3	3				2	1		1	2	→	2									
U.K.	5	8	1				3	11		7	4	→	3									
Canada	4	23	5				8	10		4	5	→	4									
Germany	9	12	7				4	12		5	9	→	5									
France	8	30	2				12	9		6	7	→	6									
Singapore	2	4	39				16	15		30	6	→	7									
South Korea	28	5	30				22	3		31	25	→	8									
Japan	26	16	17				6	7		12	8	→	9									
Ireland	6	2	28				28	6		42	20	→	10									

A MAGNET FOR FOREIGN DIRECT INVESTMENT

Canada is seeing foreign direct investment grow, with the 2019 total 42.5 per cent higher than the 10-year average.¹⁰ IBM's 2019 Global Locations Trends Report¹¹ found that Ontario had the highest number of jobs based on foreign direct investment. Numerous multinational enterprises have established AI-specific R&D centres in Toronto, Vancouver, Montreal and smaller centres, such as Waterloo. These companies include Microsoft, Google, Uber, Thomson Reuters, Samsung, IBM, Amazon, Intel, NVIDIA, LG Electronics and General Motors, among others.

The University of Toronto has AI research partnerships with each of these firms, providing invaluable experience to students and powering the region's economy. U of T has worked

with more than 600 companies in the last 10 years; about half are Canadian companies and half are the Canadian operations of multinational enterprises.

R&D partnerships between businesses and research universities transform fundamental and applied science into commercial products and services. When these partnerships are with international companies, they enable students and faculty to learn from other jurisdictions' expertise, work on leading-edge global challenges, establish channels of global collaboration and co-operation, and create opportunities for university startups to find new markets.

amazon



Calico



FUJITSU



Google



NVIDIA



AN AI PATENT POWERHOUSE

Canada’s intellectual property (IP) performance in artificial intelligence and machine learning is extraordinary. As seen in the graph below, Canada produced the most AI patents per capita among G7 nations and China between 2015 and 2018.

In Canada, there is an increasing focus on patenting as a key ingredient in economic competitiveness. Public policy debate on this issue is wide-ranging and includes a recently released report from Ontario’s Expert Panel on Intellectual Property¹² along with numerous thought leadership reports by Canadian think tanks. U of T and its partner hospitals file a patent every three days, as detailed by the University’s submission to Ontario’s Expert Panel.¹³

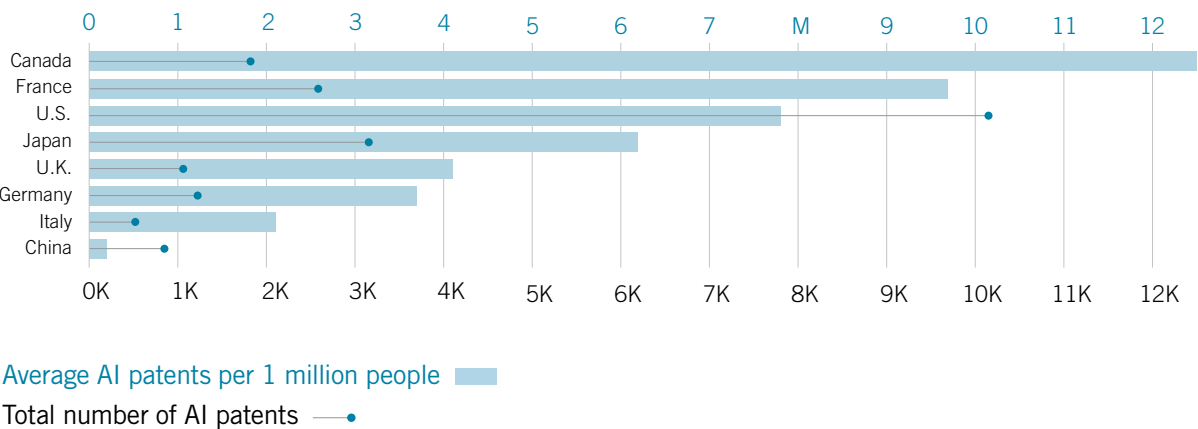
Various provincial and national efforts to accelerate innovation and productivity through IP have focused on increasing IP literacy and

sharing IP tools to a wider variety of firms. The Government of Canada’s \$85.3-million Intellectual Property Strategy, for example, includes an IP Marketplace that helps companies to find ground-breaking research from government and academia that can be licensed and commercialized.¹⁴

Similarly, Ontario’s Expert Panel on IP advised the provincial government that improving IP literacy at small, medium-sized and remote firms is critical to advancing growth in every part of the province.¹⁵

As Canada seeks to compete in a global economy increasingly focused on intangible economic assets, the AI sector can serve as an example of success in patenting and protecting Canadian ideas and products.

**Average AI Patents per Capita and Total AI Patents
G7 Countries and China, 2015–18**



THE FOUNDATION FOR CANADA'S AI LEADERSHIP: UNIVERSITY RESEARCH

The research from Global Advantage demonstrates that the Pan-Canadian AI Strategy has accelerated employment, innovation and business growth in the AI sector. From its inception, the strategy prioritized educating, recruiting and retaining researchers and talent working at the leading edge of AI.

Delivered by CIFAR, the \$125-million strategy provided:

- \$44 million to the Vector Institute (Toronto)
- \$44 million to Mila (Montreal)
- \$28.6 million to AMII (Edmonton)
- \$86.5 million for 80 Canada CIFAR AI Chairs across the three AI institutes
- Major research programs include:
 - Learning in Machines & Brains
 - AI & Society

The Government of Canada worked with provincial governments and universities to create an environment that attracts investment and encourages entrepreneurs to start AI businesses. Ontario supported the Pan-Canadian AI Strategy investment with an additional \$50 million to help launch the Vector Institute, industry has invested over \$80 million in Vector and universities have contributed by supporting faculty members and students.¹⁶

Several federal research programs have also helped Canada attract and retain world-class research talent. The flagship Canada Research Chairs

program brings significant researchers to Canadian universities, and the Canada Excellence Research Chairs program builds a critical mass of research expertise in fields of strength and opportunity.

Launched in 2017, the Canada 150 Research Chairs Program provided one-time funding to universities to attract the most talented international scholars to Canada. This program enabled U of T to recruit a world-leading scientist in AI and advanced materials from Harvard University, among others.¹⁷ Following Canada's Fundamental Science Review (Naylor Report), the 2018 Canadian federal budget increased funding to Canada's research granting councils and the Canada Foundation for Innovation, bolstering the national structure that supports fundamental research.

The federal Tri-Agencies increasingly support AI research, expanding their funding for AI-related fields by more than 50 per cent from 2014 to 2019. Social Sciences and Humanities Research Council AI-related funding increased by 680 per cent, a recognition that insights from the social sciences and humanities are critically important for the future development of AI.

These investments in fundamental research set the stage for the AI technology boom and dynamic partnerships with industry and business that test out and commercialize ideas from the lab.



BMO Lab for Creative Research

AI research is not restricted to science, technology, engineering and math fields. In late 2019, BMO made a \$5-million investment in the BMO Lab for Creative Research in the Arts, Performance, Emerging Technologies and AI. The lab will be housed at U of T's Centre for Drama, Theatre & Performance Studies, and will allow students in arts and science fields to explore how AI and other technologies can influence and be shaped by artistic expression.

UNIVERSITY OF TORONTO: ANCHORING CANADA'S AI ECOSYSTEM

The University of Toronto is one of the top research universities in the world.¹⁸ That research excellence translates into partnerships with private sector companies, cutting-edge startups and the application of AI tools across a range of sectors that impact Canadians.

The University consistently ranks in the top five in the world for overall research output. It is one of only eight universities in the world to place in the top 50 across 11 subjects, according to the Times Higher Education World University Subject Rankings.¹⁹ U of T is also Canada's most innovative university, according to Reuters' global ranking of the world's most innovative universities.

As a global hub of AI-related academic research, U of T has more than 110 faculty—including seven Canada Research Chairs, 18 Canada CIFAR AI Chairs—and 540 graduate students focused primarily on AI-related research. U of T Professor Emeritus Geoffrey Hinton pioneered deep learning neural networks at U of T, shaping and influencing today's AI industry. Hinton continues this work at the Vector Institute, along with the world's best minds in machine learning and AI.

AI is a focus of the Creative Destruction Lab (CDL), a seed-stage program founded in 2012 at the Rotman School of Management to support massively scalable, science-based companies.

From mentorship to angel investors, the CDL works with startups that employ innovations in technology and business models with the potential to deliver massive economic gains and improve human welfare. CDL responded quickly to the urgent threat of the pandemic and has launched the CDL Recovery Lab, an incubator for startups with solutions to the economic and health challenges caused by COVID-19. CDL has helped grow companies that were valued at more than \$3 billion in equity in 2019.

The University's overall research strength in areas such as health science, information technology, computer science and beyond converges with AI expertise to make U of T a source of game-changing startups that are innovating in traditional sectors and creating new ones. U of T is a world leader in fraud detection, cybersecurity and big data analysis. It is also advancing precision medicine, which draws on genetics, nanoscience and other disciplines to target disease at the molecular level.

This confluence of talent has helped U of T more than double its number of active startup companies over the past 10 years and expand AI applications to new fields. There are currently 81 active U of T startups using AI operating in Canada, with 57 formed since 2015. In the past five years, these firms have raised \$183 million and created more than 600 jobs.



Navdeep Bains, Canada's Minister of Innovation, Science and Industry, poses for photographs with Sonia Sennik, the executive director of the **Creative Destruction Lab**.

UNIVERSITY OF TORONTO AI STARTUPS



Deep Genomics is a biotechnology startup co-founded by U of T professor Brendan Frey that uses AI to build a new universe of life-saving genetic therapies. Geneticists, molecular biologists and chemists at Deep Genomics use AI to develop new ways of detecting and treating disease. The company has raised \$61 million from investors.

16 Bit is a Toronto-based company founded by Alexander Bilbily and Mark Cicero, two alumni of the University of Toronto's diagnostic radiology program with strong backgrounds in computer science and engineering. 16 Bit's vision is to augment physicians' diagnostic ability with AI-powered medical image analysis systems. The company's technologies include a screening algorithm to help radiologists interpret mammograms, and machine-learning tools that analyse neurological conditions and predict skeletal age in children to monitor their development.



Blue J Legal, co-founded by U of T law professor Benjamin Alarie, uses machine learning to make the law more transparent and accessible. Its AI-powered platforms specialize in North American tax law and Canadian employment law and enable clients to find relevant cases faster and increase research efficiency and compliance. Since graduating from the University of Toronto Early Stage Technology program, the company has received over \$11-million in capital financing and grown its team to around 50 employees.

Phenomic AI, co-founded by U of T alumnus Oren Kraus, builds computer vision tools for a faster and more accurate analysis of microscopy data. Its name refers to the "phenotype" of cells—the appearance of a cell and its internal parts. Using their AI screening tools, Phenomic AI is developing therapeutic antibodies for new drugs to treat cancer and fibrosis. The company is already working with hospitals and private sector partners.



AI SOLUTIONS TO COVID-19

“DNASTack is developing a new cloud-based network that allows researchers who are looking to improve our ability to diagnose and treat COVID-19 to share their findings.”

Justin Trudeau, Prime Minister of Canada

DNASTack, co-founded by U of T alumnus Mark Fiume, has adapted its biomedical research software to create COVID Cloud—a tool to share genetic data about COVID-19. This tool, developed with the support of Canada’s Digital Technology Supercluster, scans and indexes genomic information about the virus shared by scientists from around the world. Researchers are using COVID Cloud to track how the virus mutates as it moves through the global population.



BlueDot is a health data analytics company led by Kamran Khan, a professor at U of T’s Dalla Lana School of Public Health and an infectious disease physician at St. Michael’s Hospital. BlueDot’s machine-learning technology employs multiple data sources to detect and predict the spread of infectious diseases. The Government of Canada is using BlueDot’s technology to monitor COVID-19 and respond effectively to the pandemic. The company has raised over \$13 million.

BenchSci uses machine learning to help scientists find and purchase antibodies for their experiments, saving time and money. The company was co-founded by U of T PhD students and developed at U of T through the Entrepreneurship Hatchery, the Health Innovation Hub and the Creative Destruction Lab. With \$27 million in financing, BenchSci is now using their technology to identify novel reagents to study the COVID-19 virus.



University of Toronto researchers at the **Vector Institute** are working on multiple fronts to address the spread of COVID-19, with targeted funding from CIFAR. Marzyeh Ghassemi is developing an AI-powered chest X-ray image classifier to diagnose COVID-19. Alán Aspuru-Guzik is using AI to identify molecules that can be used therapeutically to target SARS-CoV-2—the virus that causes COVID-19. Vector is also providing high-performance computing power for the Ontario Health Data Platform.

AI FOR THE FUTURE: A \$100-MILLION GIFT

The AI ecosystem that has emerged in Canada isn't just attracting investors. Philanthropists also recognize the significance and potential for positive change. In 2019, Gerald Schwartz and Heather Reisman provided a landmark **\$100-million gift** to the University of Toronto to accelerate the joint goals of innovation, economic growth and ethical development of technology.²⁰

The gift is helping to construct the Schwartz Reisman Innovation Centre, a 750,000-square-foot complex designed to anchor U of T's unique cluster of leading artificial intelligence scientists and biomedical experts, its world-class entrepreneurship network, and the country's largest concentration of student- and faculty-led startups.

Their leadership and vision included establishing the Schwartz Reisman Institute for Technology and Society, whose mission is to explore and address the ethical and societal implications of AI and other emerging technologies. The Schwartz Reisman Institute facilitates cross-disciplinary research and collaboration and will draw on insights from across the sciences, humanities and social sciences to explore the social and economic benefits and challenges that AI, biotechnology and other technological advances present for Canadians.

Designed by Weiss/Manfredi, the **Schwartz Reisman Innovation Centre** will anchor U of T's cluster of world-leading AI scientists and biomedical experts and create an unprecedented concentration of research-based startups.



“Canada stands poised to be the source of the creativity and innovation in producing AI that is safe and beneficial for us all. In AI too, the world needs more Canada.”

Gillian Hadfield, Executive Director,
Schwartz Reisman Institute

CONCLUSION: LEARNING FROM CANADA'S PAN-CANADIAN AI STRATEGY

The success of the Pan-Canadian AI Strategy suggests that government can accelerate the creation of firms and economic growth in strategic and emerging sectors by investing in research and talent. Canada's strategic government investments have spurred private sector activity and secured Canada's global leadership in technologies that are increasingly driving economic growth and prosperity. The Strategy also demonstrates how government action can address the challenge of boosting private R&D investment across the Canadian economy, raising productivity and living standards.²¹

A key question now facing Canada is whether the country can sustain its first-mover advantage in AI or whether other countries' investments will overtake Canada's leadership. For example, Germany and France have committed billions of dollars to match their vision of long-term economic growth driven by data and machine learning.²² Recent challenges suggest that now is the time for co-ordinated national action to maintain our position and strengthen our global role in this sector.

The national effort to arrest the spread of COVID-19 has demonstrated that AI companies and talent are a powerful resource for facing complex challenges. For example, through its partnership with BlueDot, the federal government is deploying Canadian technology to track the viral outbreak. As Canada's economy continues to be

tested by the effects of the pandemic, the talent recruited and retained by Canada's Pan-Canadian AI Strategy is collaborating with the private sector, startups, universities and hospitals to bolster the country's public health response and restore its economy. Supporting talent working across these sectors will assist homegrown firms to scale into major multinational players through advanced research and collaboration.

More broadly, Canada should look to the success it has had in AI and be prepared to seize opportunities in other emerging sectors. The Tri-Agencies have been proactive in advancing the research-based innovation ecosystem through the development of new funding programs and recent investments in fundamental science. Today, there are numerous fields where Canada's global research strengths and leadership can supply the foundation for commercial success, such as regenerative and precision medicine, advanced materials, autonomous health care, logistics, robotics and quantum computing.

If Canada's government can replicate the success of its AI strategy in other sectors, the country will demonstrate once again how the public and private sectors can collaborate to drive successful commercialization and increase our global competitiveness. The result will be a country ready to prosper from—indeed, at the centre of—the coming technological transformations that will reshape how we live.

A Replicable Model

A number of key actions led to Canada's leadership in the AI sector. These actions can inform and motivate successful strategies and opportunities in other areas of technological development.

- Invest in emerging areas of global significance, where the opportunity to leverage private investment is high
- Take advantage of Canada's current research and industry strengths
- Focus equally on fundamental research and on knowledge translation and commercialization
- Invest in attracting global talent
- Support the launch and growth of promising startups that commercialize leading-edge Canadian research

Endnotes

- 1 *Canada's AI Ecosystem Impact Assessment*. Global Advantage Consulting Group (2020)
- 2 *Canada's AI Ecosystem Impact Assessment*. Global Advantage Consulting Group (2020)
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- 8 The Global AI Index was developed by Tortoise Intelligence and is structured around three main pillars: investment, innovation and implementation. The investment pillar covers commercial ventures and government strategy, with metrics reflecting financial and procedural commitments to artificial intelligence along with commercial ventures and government strategy. The innovation pillar covers research and development, with metrics reflecting technology breakthroughs and advancements in methodology that are indicative of greater capacity for artificial intelligence in the future. Finally, the implementation pillar covers talent, infrastructure and operating environment, with metrics reflecting the operationalizing of artificial intelligence by practitioners in business, government and communities.
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