Centre for International
Governance Innovation

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Table of Contents

About the Author

Douglas (Doug) Lippoldt is a CIGI senior fellow and an international trade economist based in Claremont, California. He served as chief trade economist at HSBC Global Research from 2014 to 2020. Previously, he served in various roles as a senior economist at the Organisation for Economic Co-operation and Development in Paris, France, during a tenure of 22 years. Doug's early career included seven years as an international economist with the US Department of Labor.

He has published extensively on trade topics as well as on related aspects of economic development, labour market adjustment, innovation and intellectual property. Doug holds a Ph.D. in economics from the Institut d'études politiques de Paris (Sciences Po), an M.A. in international studies from the University of Denver and a B.A. in international studies from Washington College in Maryland. He was a Fulbright Scholar at the University of Cologne, Germany, and a Peace Corps volunteer in Burkina Faso. During 2015–2019, he represented HSBC as the deputy delegate on the Business 20 Trade and Investment Task Force. He is currently a contributing author on a Think20 trade task force team.

Acronyms and Abbreviations

AI	artificial intelligence
AIDA	Artificial Intelligence and Data Act
AIIA	Artificial Intelligence Industry Alliance
APEC	Asia-Pacific Economic Cooperation regional forum
B2B	business-to-business
BIS	Bureau of Industry and Security (US)
CAC	Cyberspace Administration of China
capex	capital expenditure
CPTPP	Comprehensive and Progressive Agreement for Trans-Pacific Partnership
CUSMA	Canada-United States-Mexico Agreement
DPA	Digital Policy Alert
DSIT	Department for Science, Innovation and Technology (UK)
ESG	environmental, social and (corporate) governance
FATF	Financial Action Task Force
FTC	Federal Trade Commission (US)
G7	Group of Seven
G20	Group of Twenty
GDPR	General Data Protection Regulation
ICB	Industry Classification Benchmark
IFAC-BIAC	International Federation of Accountants and Business at OECD
IP	intellectual property
IPRs	intellectual property rights
LLMs	large language models
NIST	National Institute of Standards and Technology (US)
OECD	Organisation for Economic Co-operation and Development
p.p.	percentage point
R&D	research and development
SAG-AFTRA	Screen Actors Guild-American Federation of Television and Radio Artists
UNESCO	United Nations Educational, Scientific and Cultural Organization
USTR	Office of the United States Trade Representative
VC	venture capital
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

Executive Summary

In view of the pace of technological change in the artificial intelligence (AI) sector, this paper considers leading AI-intensive innovator firms and the state of the regulatory environment in which they operate. A central concern is to examine the concentration of AI innovation and to consider factors in the regulatory environment that may support or hinder its responsible diffusion in line with applicable international norms. In order to achieve broad welfare gains and global participation in the AI economy, stakeholders — producers, suppliers, consumers, researchers, regulators and others — will need a safe and trustworthy business environment that facilitates responsible access and technology diffusion.

The analysis rolls out over three main sections. The first section provides a substantial survey of relevant items from the recent literature on AI innovation. The second section, a two-part analytical exercise, identifies an illustrative list of innovative AI-intensive firms. Separate data sets highlight publicly listed leading research and development (R&D) firms and successful start-ups. A series of screens based on expert opinion and enterprise-affiliation groups is used to select leading AI firms from each of these two populations. Relevant characteristics are examined, revealing, in particular, the extent of geographic concentration of these leading innovative AI businesses. The third section provides a quantitative review of regulatory developments concerning AI, conducted with a particular focus on the home countries of the AI-intensive firms. This includes analysis of two different policy and regulation databases to examine topics of emphasis and the pace of regulatory change. The rise in regulatory activity is documented, as is the focus on matters of safety, transparency and data.

The conclusion highlights particular AI-relevant economic and regulatory features drawing on the combined findings from the three sections and presents recommendations. On the basis of the empirical assessment, the paper raises concerns about the cost of misalignment in the regulatory framework, which could unduly interfere with diffusion of beneficial AI technology and dampen incentives for further innovation.

In light of these points, the paper makes four key recommendations. First, the designation of an international institution to lead on AI regulatory cooperation. National governments — perhaps via a joint decision of the Group of Twenty (G20) — should establish a designated AI body at the global level to monitor regulatory developments and support coordination on regulatory measures. Such an institution could help to promote alignment, AI safety and best practice.

Second, prioritization of regulatory coherence. International regulatory cooperation promotes coherence and should be advanced. And, coherence should be an objective at all levels, including among domestic regulatory bodies. In the case of the AI sector, this should include, on a priority basis, coherence for AI safety measures, as well as transparency provisions (for AI systems and regulatory processes) and data management regulations (to ensure protections are effective).

Third, building transparency into regulatory processes and AI systems. In light of the complexity and the potential capabilities of AI technology, it is important that the principle of transparency be embedded systematically. For example, AI system users need to be aware when they are interfacing with an AI system and when products or services they encounter are AI-generated. In addition, businesses and regulators are more likely to achieve intended results efficiently when regulatory processes are clear and predictable.

Fourth, promotion of well-regulated data management. This should protect subjects' personal data as well as third-party intellectual property rights (IPRs), and provide clear information on data provenance and its nature, while facilitating responsible data access where appropriate for AI system development.

Introduction

AI (see Box 1), a field with its roots established back in the 1950s,[1] has grabbed an increasing share of public attention over the past few years. According to data supplied by Google's Bard, in 2022 approximately 8.5 billion Google searches referenced the term "artificial intelligence," double the volume in 2016.[2] A portion of the increased public interest is driven by the success of recent generative AI releases such as ChatGPT 3.5 (in November 2022) and Google's Bard (in March 2023). These chatbots can communicate rapidly in plain language terms, delivering expansive narrative responses drawing on a wealth of information, albeit with occasional incorrect conclusions.[3] Other AI-powered content generation interfaces such as DALL-E, Midjourney and Stable Diffusion can deliver images based on text inputs. Suddenly, AI is much more in the public eye and it is capable of doing useful things for casual users as well as experts.[4]

The rollout of AI over the coming decade could be a very big deal indeed. A team from Goldman Sachs estimates that generative AI could bolster productivity growth, adding more than a quarter point to global annual GDP growth by 2034, net of offsets (Hatzius et al. 2023, 14, exhibit 18). In the distribution of the growth gains associated with AI, the Goldman Sachs team expects developed economies to outpace emerging market economies. For example, the United States could boost its annual GDP growth by 0.45 percentage point (p.p.) and Canada could do so by more than 0.35 p.p. Japan would add roughly 0.33 p.p. and leading European economies between 0.25 p.p. and 0.30 p.p. For China, the annual gain is estimated to be a bit more than 0.15 p.p., while Brazil would gain more than 0.10 p.p. and Russia just about 0.10 p.p. The impact on Indian GDP would be neutral.

In view of the pace of technological change in the AI sector, this paper considers leading AI-intensive innovator firms and the state of the regulatory environment in which they have been operating. A central concern is to examine the concentration of AI innovation and to consider factors in the regulatory environment that may support or hinder its responsible diffusion in line with applicable international norms.[5] In order to achieve broad welfare gains and global participation in the AI economy, stakeholders — producers, suppliers, consumers, researchers, regulators and others — will need a safe and trustworthy business environment that facilitates access and international diffusion.

The paper is structured to take stock of AI and innovation as seen from the perspectives of economic literature and sketch their concrete manifestation in the economy as seen in firm-level data. Then, in light of the geographic and structural concentration that is revealed, the paper turns to consider the points of emphasis in the emerging regulatory framework, to highlight areas that may inhibit or facilitate the diffusion of AI innovation. The conclusions highlight steps that could be helpful in supporting the diffusion of AI innovation. The paper aims to add to the literature on AI innovation and its diffusion by delivering analysis drawing on a unique combination of firm-level data sources and policy indicators.

The analysis rolls out over three main sections and two appendices, and contains the following:

- A substantial survey of relevant items from the recent literature on AI innovation.
- A two-part analytical exercise to identify innovative AI-intensive firms, considering publicly listed, R&D-expenditure-leading

1 Two early foundational elements in the history of AI were the publication of an article titled "Computing Machinery and Intelligence" by Alan Turing (1950) and the coining of the term "artificial intelligence" in a 1955 proposal from a team led by John McCarthy for a Dartmouth summer research project to be held the following year (McCarthy et al. 1955).

2 The text refers to a response to the author's query via Google's Bard on December 3, 2023. The reply included the disclaimer, "Bard may display inaccurate info, including about people, so double-check its responses." Also, note that in several steps between December 6, 2023, and February 8, 2024, Google upgraded and rebranded Bard as Gemini. See https://gemini.google.com/updates. (NB, Alphabet is the parent company of Google.)

3 Indeed, while AI advances such as the leap in linguistic capabilities of large language models (LLMs) are real enough, there is also an element of euphoria among users. Some scholars caution that there is overselling of the actual AI achievements, perhaps already anticipating the next steps in AI development (Bender et al. 2021; Murgia and Thornhill 2023).

4 With respect to experts, for example, a headline in Stanford University's *Artificial Intelligence Index Report, 2023* states: "DeepMind Trains Reinforcement Learning Agent to Control Nuclear Fusion Plasma in a Tokamak" (Maslej et al. 2023, 4). DeepMind is an AI model developed by a UK start-up acquired by Google in 2014. A tokamak is a kind of magnetic field device employed to contain plasma.

5 For example, see the Organisation for Economic Co-operation and Development (OECD) principles on AI in Appendix 2 of this paper and in OECD (2019).

Box 1: What Is AI?

There is not a universally accepted definition of AI. The OECD (2024, 4) provides one of the most cited: "An AI system is a machine-based system that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments. Different AI systems vary in their levels of autonomy and adaptiveness after deployment."

enterprises and privately held unicorns (a unicorn is a successful start-up valued at US$1 billion or more). A series of screens based on expert opinion and enterprise-affiliation groups are used to select AI leaders from each of these two populations. The result is an illustrative case study of leading AI-intensive innovators. Their firm-level characteristics are examined.

- A quantitative review of regulatory developments concerning AI is conducted with a particular focus on the home countries of the AI-intensive firms. This includes analysis of two different policy and regulation databases to examine key topics for AI innovation, the pace of regulatory change and the elements relevant for diffusion of AI technology.
- The conclusions highlight AI-relevant economic and regulatory features, drawing on the combined findings from the analyses, and point to policy elements that could be usefully included in support of AI innovation in next steps as the AI regulatory regime is fleshed out.
- A data appendix provides information on the screens employed to select leading AI firms from the pool of R&D expenditure leaders. A regulatory appendix contains detailed background notes on the emerging AI regulatory regimes in each of the major AI economies: China, the European Union and the United States. Canada is included as an illustrative case of a smaller economy active in AI innovation and regulatory matters.

Literature: Rapid Technological Development, Unsettled Scholarship

The literature review presented here aims to provide an illustrative survey of research examining AI innovation with a particular emphasis on LLMs and related data matters. LLMs and data were selected as they have attracted particular interest from policy makers. The review then moves to consider risk and AI, which is a key factor cited by policy makers in taking steps to build out the regulatory regime. In view of concerns about concentration in the sector, the review next turns to consider technology diffusion and, as an important factor in that regard, intellectual property (IP). Finally, the literature review closes with a section on governance and AI, setting the stage for the subsequent analysis and policy conclusions.

Of LLMs and Data

LLMs have operationalized the concept of AI in a manner that has caught public attention thanks to recent innovative consumer-facing products such as ChatGPT and Bard. Nvidia defines LLMs as "deep learning algorithms that can recognize, summarize, translate, predict, and generate content using very large datasets."[6] Development of these models dramatically accelerated following the publication of a breakthrough paper by a team primarily based at Google. Ashish Vaswani et al. (2017) found that

6 See Nvidia's website (www.nvidia.com/en-us/glossary/large-language-models/) for a more detailed explanation of LLM architecture. LLMs are one type of generative AI, which is any AI system whose primary function is to generate content.

a simplification of the structure for AI models and the use of parallel processing of data based on an architecture dubbed "the Transformer" could reduce training times and improve accuracy. Wayne Xin Zhao et al. (2023) provide a sweeping survey of the development of such LLMs. They highlight four major aspects: pre-training, adaptation tuning, utilization and evaluation. The emergent abilities of these models shine once they are exposed to large pools of data and attain critical size thresholds, and their capabilities include in-context learning, instruction following and step-by-step reasoning. With respect to tuning of LLMs, Zhao et al. (2023) note the importance of safety and aligning of the models with human values.

Indeed, innovation processes must also operate within the constellation of larger societal concerns. Susan Ariel Aaronson (2024) spotlights the development of LLMs that depend on training that uses large pools of public and proprietary data from around the world. Often such data is obtained through a process of web scraping (harvesting data as opportunities permit). This data may include personal information. The data may be incomplete, false or biased, and it may be difficult to confirm whether it is accurate, respectful of IPRs (especially copyright protection) and in accord with required consumer protection (which may depend on informed consent of the data subjects). Regulators have struggled to keep up with the expanding scale and technological complexity of AI. Aaronson advocates a systematic approach to deliver a coherent regulatory framework that takes into account the complexity of systems and the broad range of stakeholders across sectors and disciplines.

As Aaronson and Patrick Leblond (2018) note, the World Trade Organization (WTO) has not been able to find traction for a multilateral approach to cross-border trade in data. Indeed, data issues are an important element in the current WTO plurilateral e-commerce negotiations.[7] With initial discussions launched in 2017, and agreement to launch negotiations in 2019, the talks were intended for conclusion in 2022. However, in part due to a lack of consensus around the handling of data localization requirements and cross-border data flows, the talks remain ongoing. Meanwhile, the United States (Office of the United States Trade Representative [USTR] 2023) recently announced that it was withdrawing support for provisions that might interfere with its own data and source code regulation.[8] Thus, it is perhaps not surprising that the co-convenors of the talks (Australia, Japan and Singapore) advocated — without success — concluding the talks in 2023, even without wrapping up the contentious data issues (WTO 2023).[9]

Commitments embedded in some recent regional and bilateral trade agreements aim to discipline protectionist measures with respect to data, while protecting IP (including trade secrets) with respect to software. For example, the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP)[10] and the Canada-United States-Mexico Agreement (CUSMA) both constrain government recourse to data localization requirements, protect free flow of data for business purposes and shield computer source code (including algorithms). These accords provide some flexibility (for example, for legitimate public policy objectives and law enforcement). They also mandate a degree of protection for personal information. Still, Leblond (2021) argues that data and source code provisions may prove problematic for Canada in establishing a legal framework for its objective of "trust in the digital age." For example, it is not clear whether these two accords would permit Canada to identify and remedy algorithmic bias. Instead of regulating these points as trade matters, Leblond (ibid., 315) makes the case for a separate international body (for example, an International Data Standards Board) to be "responsible for setting standards that regulate

7 A plurilateral agreement is one in which individual WTO members may opt in and participate or not. As of October 23, 2023, 90 WTO members were participating in the negotiations for the Joint Initiative on E-Commerce at the WTO. See www.wto.org/english/tratop_e/ecom_e/joint_statement_e.htm.

8 The USTR statement (USTR 2023) says, "Many countries, including the United States, are examining their approaches to data and source code, and the impact of trade rules in these areas. In order to provide enough policy space for those debates to unfold, the United States has removed its support for proposals that might prejudice or hinder those domestic policy considerations. The JSI [Joint Statement Initiative] continues to be an important initiative and the United States intends to remain an active participant in those talks."

9 The co-convenors noted that the initiative as of October 2023 had concluded 12 articles: online consumer protection; electronic signatures and authentication; unsolicited commercial electronic messages (spam); open government data; electronic contracts; transparency; paperless trading; cybersecurity; open internet access; electronic transaction frameworks; electronic invoicing; and single windows (WTO 2023). Also, on March 2, 2024, at the WTO Ministerial in Abu Dhabi, WTO ministers outlined next steps in the Work Programme on Electronic Commerce and agreed to renewing a two-year moratorium on customs duties on electronic transmissions (WTO 2024).

10 The members of the CPTPP are Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore and Vietnam. The accession of the United Kingdom is awaiting ratification.

the creation, processing, use, distribution and transfer of data, both personal and non-personal."

Access to quality data also presents a problem, with data being a primary resource driving AI performance (see, for example, Bender et al. 2021). Algorithm outputs depend on appropriate data inputs. The issues extend beyond simple access to abundant data sources. They also concern risks with respect to issues such as privacy, security and IPRs. Absent a comprehensive global norm, various national and regional governmental initiatives are aiming to address some aspects of the shortfall (for example, see Appendix 2). The private sector is also active in efforts to improve standards. One such initiative is the Data and Trust Alliance,[11] a grouping of 26 organizations ranging from Johns Hopkins University and the Smithsonian Institution to enterprises of various sizes from unicorns (for example, Transcarent) to behemoths (for example, Meta). These entities have come together to develop a proposed standard for data provenance labelling. Their concept is for each data set to be associated with a unique ID and standardized metadata including: lineage (constituent data), source (of the current data set), applicable legal rights, privacy and protection (data sensitivities), generation date for the current data set, data type (for example, structured/unstructured), generation method (for example, machine learning or industrial sensors), and intended use and restrictions (for example, limits to access by third parties).

AI Innovation and Risks

AI innovation has economy-wide implications and poses a challenge for smaller economies that have limited capacity to influence emerging standards that help shape outcomes. Dan Ciuriak and Anna Artyushina (2023) point out that the recent dramatic expansion of AI capabilities will be followed by a continued stream of innovation in the pipeline, as evidenced by the upturn in the pace of AI patent filings. From AI sector behemoths to thousands of developers in small start-ups, businesses are looking to expand and leverage the commercial potential of emerging AI technology. Ciuriak and Artyushina highlight the implications in three major issue areas for Canada, but these points are also relevant elsewhere. First, "machine knowledge capital" (as they call it) will affect every sector and arouse public concern across the board. Second, despite Canada's active role in AI R&D, investment and entrepreneurship, the nation will largely depend on imported AI assets shaped by others. Where Canada does export AI products, it will be subject to standards set by the major players and not its own. Third, the AI transformation will drive a talent shortage, as required skills and knowledge are in short supply. This highlights again the challenges for smaller economies to benefit fully from global AI sector growth.

The risk profile of AI technology is unique in comparison to traditional software risks, a point underscored by the US National Institute of Standards and Technology (NIST) (2023). Existing standards and best practices currently employed in various organizations may not be adequate for mitigation of the risks posed by AI systems. For example, data employed in training AI may change over time in a way that undermines system reliability and trustworthiness. Moreover, AI systems can be quite complex, making it difficult to detect and respond to failures when they occur. Eli Fathi and Peter MacKinnon (2023), for example, point out the risks of undetected bugs and biases embedded in AI systems. Also, as NIST (2023, 1) highlights, AI systems are "inherently socio-technical in nature, meaning they are influenced by societal dynamics and human behavior." In other words, AI risks may emerge due to societal factors that affect how systems are developed and employed (for example, embedding race or gender discrimination). And, these risks come on top of the risk that AI might be intentionally misused to amplify harms such as violation of personal privacy, expansion of non-competitive markets, manipulation of individuals and dissemination of hate, lies and misinformation (Wheeler 2023).

As NIST (2023, 1) puts it, "Without proper controls, AI systems can amplify, perpetuate, or exacerbate inequitable or undesirable outcomes for individuals and communities. With proper controls, AI systems can mitigate and manage inequitable outcomes." In response, NIST proposes a four-function framework to address organizational AI risk. The goal is to govern, map, measure and manage risk. Governance aims to cultivate a culture of risk management. Mapping aims to identify contexts and associated risks. Measurement aims to track, assess and analyze identified risks. Management aims to prioritize risk response based on projected impacts. This voluntary framework is intended

11 Details of the Data and Trust Alliance can be found on its website: www.dataandtrustalliance.org.

to foster the responsible design, development, deployment and use of AI systems over time. Its processes can support the effective implementation of responsible AI principles being developed by various stakeholders, including organizations such as the OECD (2019) and leading AI firms.[12]

Technology Diffusion

Despite risks, the diffusion and application of AI technology is well under way. The McKinsey Global Survey on AI for 2022 (Chui et al. 2022) found that AI applications were being employed in at least one-half of surveyed firms, up from just one in five in 2017.[13] Among the firms with AI capabilities, those most frequently implemented included robotic process automation (39 percent), computer vision (34 percent), natural-language text understanding (33 percent) and virtual agents or conversational interfaces (33 percent). The results of implementing AI capabilities varied, but tended to be stronger in terms of the share of respondents reporting revenue enhancement (63 percent) than cost savings (32 percent). Respondents most often reported revenue gains when they implemented AI capabilities in marketing and sales or in product and service development. AI-related cost decreases were most frequent with respect to supply chain management. Firms that have succeeded in integrating AI into their operations have tended to compound those gains over time.

Lewis Ho et al. (2023) point out that some developing countries could benefit greatly from AI but may lack resources, infrastructure or training to take advantage of AI systems. Commercial AI technology development may not align with these needs, being oriented instead toward developed countries as priority markets. Coordination and public-private partnerships may be needed to help address such market failures. Even where market conditions might support diffusion, the lack of a global AI governance framework could lead to blockages. Ho et al. (2023) underscore the potential costs of inconsistent national regulations, which may slow AI deployment. Such inconsistencies weaken incentives to invest in an innovation or to export AI technologies to an outlier country.

The failure of big technology firms to exploit some local opportunities may provide a bright spot for developing countries looking to participate in the AI boom. Saurabh Mishra et al. (2023) highlight the potential for AI to play a role in strategic diversification for developing countries. They note a growing computing divide whereby comparatively few countries have domestic capacity to develop and train large-scale AI models. The authors cite the statistic that as of 2023, 100 percent of the world's supercomputers reside in only 30 nations. Moreover, to put original AI development into production, human capital, software, data, computational power and new management practices are generally required. Yet, once trained, AI technology can be quite portable and adaptive. As Mishra et al. (2023) note, countries that already have sectoral specialization may find an advantage in developing tailored AI applications around such sectors and their data. This may provide a means for emerging market economies to stimulate AI-sector development.[14] In addition, Kai-Fu Lee (2018) notes that some algorithmic training can be transferred internationally, but other training may prove irrelevant or even harmful. Local staff may be required to identify and respond to local variation, thereby providing further entry points for AI sector participation.

IP

As with many technology-led developments, IP protection is playing a role to incentivize AI development.[15] It does this in a variety of ways. It may be used to overcome market failures and ensure a measure of market exclusivity for a product such that returns accrue to the commercial innovator. It may also be used to prevent exclusive appropriation of an innovation and thereby protect openness for research and the operation of the

12 See, for example, Google's and Nokia Bell Lab's work at, respectively, https://ai.google/responsibility/responsible-ai-practices/ and www.bell-labs.com/research-innovation/ai-software-systems/responsible-ai/#Six-pillars-of-Responsible-AI.

13 The McKinsey Global Survey on AI was conducted online in May and August 2022 with 1,492 participants from "the full range of regions, industries, company sizes, functional specialties, and tenures" (Chui et al. 2022). The survey was conducted annually from 2017.

14 Mishra et al. (2023) find that AI specialization in a given sector tends to be associated with subsequent AI specialization in certain other sectors. For example, they found a relationship between AI specialization in metal products and the adjacent sector of robotic automation (ibid.). Mexico has a revealed comparative advantage in the metal products sector. The authors conclude that Mexico may wish to consider promotion of investment in robotic automation as a way to develop further AI specialization, leveraging its existing specialization in metal products.

15 The WTO Agreement on Trade-Related Aspects of Intellectual Property Rights provides a global minimum standard of protection, aiming to facilitate trade and investment.

sharing economy.[16] There are many possibilities. Regardless which one, IP is likely be part of the discussion. Getting the IPRs protection tuned to address challenges around a new technology may require a period of collecting experience to identify the key issues, impediments and gaps in the system. Use and adjudication of IPRs based on existing laws may provide essential information for subsequently legislating adjustments in the system.

With AI, IPR issues are already coming to the fore. Generative AI is raising copyright issues both with respect to training data employed (which may be subject to copyright protection) and with respect to asserting copyright for products developed without sufficient human input. A recent assessment by the US Congressional Research Service advised that it may be premature to legislate on such matters until the courts have a chance to adjudicate and identify any shortfalls in the legal framework (Zirpoli 2023). (Next up for dispute may be the IPR-adjacent issue of control over one's own image, voice and actions in AI-generated content.)[17]

Similar issues may arise with respect to patents, where the notion of human-directed creation may need legal clarification. In trade secrets, challenges are emerging in relation to disclosure of algorithms, restrictions on labour mobility and appropriation of data, among other issues, particularly in light of the high value of R&D in the AI sector. Regulatory processes such as customs controls of source code or registration of models for approvals (for example, already required in China and pending in the United States and the European Union; see Appendix 2) may present further challenges for protecting trade secrets. It is unclear whether the current IPR framework will prove adequate or novel challenges will require changes in legislation and regulation.

Getting the IPRs system tuning right can make a difference for the diffusion of a technology. Work at the OECD and elsewhere has provided evidence that adequate IPR protection can be conducive to trade and investment in technology-intensive products and to technology transfer via licensing of IP (Cavazos Cepeda and Lippoldt 2010; Branstetter, Foley and Saggi 2010; Lippoldt and Schultz 2014). These effects appear to be strongest with respect to patents, but positive associations have also been found in some cases for copyright, trademarks and trade secrets. Where holders of IP have means of protecting their assets, they are more inclined to transfer control to unaffiliated parties (Park and Lippoldt 2005). And likewise, when foreign firms looking to invest directly in a nation are able to protect their IPRs, they are more likely to transfer recent generation technology along with the knowhow to successfully exploit it (Park and Lippoldt 2014). It is likely that similar tendencies will manifest with at least some elements of AI sector technology.

A significant distinction with respect to IP and AI concerns the difference in methods between the open-source LLM development community, which employs an open approach with liberal licensing terms, and the developers building proprietary LLMs, asserting their IPRs and holding back some information that conveys commercial advantage. The former are perhaps able to leverage their technical efforts due to inputs from outside contributors, leading in some cases to advances in model development. The latter may be incentivized in their efforts by better access to investor capital and advice in some cases (although, not all will avail themselves of these options), as well as the prospect of financial gains in the event of commercial success.

The open-source versus proprietary divide echoes through the AI ecosystem (CB Insights 2023b), although there is significant cross-fertilization among developers using either approach (Kaye 2022). Open-source tools such as PyTorch, TensorFlow and PaddlePaddle have been developed and released by major AI developers (Meta,[18] Google and Baidu, respectively). Such tools have benefited,

16 For example, copyright protection might be used by a software originator to maintain certain rights over their open-source software creation while making the code readily and freely available for use by subsequent innovators to build upon or even modify, depending on the terms of an open-source licence.

17 The complexity of generative AI concerns was illustrated in the United States by the contract negotiations between the Screen Actors Guild–American Federation of Television and Radio Artists (SAG-AFTRA) and the Alliance of Motion Picture and Television Producers. The deal, ratified on December 5, 2023, defines AI performance concepts such as an "independently created digital replica…used to portray the performer in scenes they did not actually shoot" and generative AI "used to simulate a performer's voice, facial expressions, and movements to create entirely new content" (SAG-AFTRA 2023a, 2). Each use of AI is subject to the consent of the subject, clear delineation of the AI content to be created, and appropriate compensation. The contract includes a principle of primacy for human performance in the realm of acting, the holding of regular employer-union meetings on the evolving use of AI, and monitoring of implementation (SAG-AFTRA 2023b).

18 Note that in September 2022 Meta transferred control of PyTorch to the Linux Foundation (Kaye 2022).

among others, smaller independent application developers, including those collaborating internationally and thereby promoting diffusion of innovation. Hosting services such as GitHub and Hugging Face have enabled developers to share code and data. AI as a service provider may deliver proprietary cloud-based solutions to expedite AI development and deployment for users, while in some cases drawing on open-sourced inputs (for example, see Wren 2023).

Recent top-performing LLMs have tended to be built using proprietary approaches. However, there is an ongoing exchange with the open-source community, and by some measures the performance of open-source LLMs is catching up (Chen et al. 2023; Bremmer and Suleyman 2023, 30). Giant firms such as Meta (with Llama 2) and Microsoft (with Phi), and academic institutions such as Stanford (with Alpaca) have released pre-trained, open-source models, benefiting indirectly from new insights as outside researchers and developers contribute to advance the technology. This leverages talent from the open-source community and can add new vitality to innovation processes. It may also permit small businesses to participate in the AI economy by tailoring and marketing their own elements built on an open-source AI foundation. Given the substantial original LLM development costs, an open-source approach provides some small firms with a useful point of entry to the AI market.

The accelerated pace of development from both approaches has led to AI safety concerns, particularly with respect to frontier model development that may unleash new or poorly understood capabilities (Department for Science, Innovation and Technology [DSIT] 2023). Open-source developments raise particular concerns. Downstream evolution of open models may not be adequately tracked; existing guardrails and built-in mitigation measures may not be sufficient to ensure AI safety (Fathi and MacKinnon 2023; Raskin and Harris 2023). As Ian Bremmer and Mustafa Suleyman (2023, 41) put it in a recent article, "The devolved nature of AI development and core characteristics of the technology, such as open-source proliferation, increase the likelihood that it will be weaponized by cybercriminals, state-sponsored actors, and lone wolves."

As a consequence of such concerns, the United Kingdom convened a safety summit among 29 governments in November 2023. One result was the Bletchley Park Declaration whereby participants agreed to redouble their cooperation on AI safety (for example, through identification of safety risks and building risk-based safety policies) and to engage stakeholders to take responsibility when undertaking advanced model development work (for example, through external pre-release safety testing) (GOV.UK 2023).[19]

Governance

Mardi Witzel and Niraj Bhargava (2023) provide a concise overview of the state of play with respect to AI governance.[20] They briefly consider key elements of governance such as national strategies, ethical AI frameworks, current and proposed legal and regulatory instruments (notably in the European Union, the United States and Canada), AI standards (highlighting the International Standards Organization, ISO 42001 standard for AI management systems and the NIST AI Risk Management Framework). The authors' review makes clear that these various elements each have a role and their development remains a work in progress. With respect to balancing among the various elements of governance, Tom Wheeler (2023, 20) notes, "All modern regulations walk a tightrope between protecting the public interest and promoting innovation and investment. In the AI era, traversing the regulatory tightrope means accepting that different AI applications pose different risks and identifying a plan that pairs the regulation with the risk while avoiding innovation-choking regulatory micromanagement."

Bremmer and Suleyman (2023) make the case for early action on the establishment of a global governance mechanism for AI. They highlight the nature of AI as a general purpose technology that is rapidly evolving and capable of myriad applications and, potentially, self-improvement. At some point, AI will exceed human mental performance in a general manner. This has significant potential for good, such as through its ability to accelerate innovation processes, its potential to enhance

19 In relation to international cooperation on AI safety, the Bletchley Park summit was a timely follow-up to the recent Group of Seven (G7) Hiroshima meeting. The G7 Leaders' Communiqué, May 20, 2023, paragraph 1, stated: "We are determined to work together and with others to: …advance international discussions on inclusive artificial intelligence (AI) governance and interoperability to achieve our common vision and goal of trustworthy AI, in line with our shared democratic values." See White House (2023a).

20 The authors (2023) tackle AI governance from a unique environmental, social and (corporate) governance (ESG) perspective, whereby AI could be integrated into ESG reporting requirements.

productivity, and its anticipated capacity to assist in responding to global crises such as health or climate emergencies. However, AI will cause dislocation in labour markets and it has the potential for misuse in areas such as disinformation, surveillance or even the creation of autonomous weapons, among other possibilities. It may also exacerbate inequalities. Leading AI nations such as China and the United States will compete for AI leadership, but most countries will access AI in a secondary manner.

Given the low marginal cost of replication of AI models, the unknowable nature of future AI developments and the risks of misuse of these technologies, Bremmer and Suleyman (ibid.) argue for establishment of a three-part global AI governance regime. First, they suggest establishment of a global scientific body, similar to the UN Intergovernmental Panel on Climate Change, to advise governments on emerging AI challenges. Second, they propose an international body to manage tensions among major AI powers (for example, China and the United States), to establish guardrails and monitoring, and to prevent proliferation of dangerous advanced AI systems. Third, the authors propose a technocratic body for AI risk — a Geotechnology Stability Board[21] — to engage national regulators, international standards bodies and private sector multinational stakeholders in preventing or responding to AI crises, and governing open-source AI. Across these three bodies, regulatory mechanisms might be considered such as "know your customer" transparency standards, licensing requirements, safety testing protocols and product registration and approval processes, among others.

According to Bremmer and Suleyman (ibid., 36) the AI governance regime should "identify and mitigate risks to global stability without choking off AI innovation and the opportunities that flow from it." They call this "technoprudentialism," an approach that would be guided by common principles: an appropriate degree of precaution (first, do no harm); regulatory agility in anticipation of technological changes; inclusivity (engaging AI stakeholders including governments, private sector AI firms and civil society experts such as scientists, ethicists, trade unions, among others); impermeability, meaning blanket coverage globally; and targeting actions depending on the risks in specific contexts (rather than one-size-fits-all).

Ho et al. (2023) call for an Advanced AI Governance Agency to set international standards, support implementation of standards and monitor compliance. They suggest establishment of institutional capacity for several further functionalities, either via stand-alone institutions or in some combination: an AI safety project to conduct or support research; a scientifically oriented commission on frontier AI to identify opportunities and risks, and contribute to policy consensus around these; and a public-private frontier AI collaborative to develop this technology, manage dual-use applications, educate, and support diffusion and access. In developing these functionalities care will be required to avoid encumbrances of the type that hinder the institution's agility and responsiveness.

Leading AI-Intensive Firms: A Few Stylized Facts

A few comparative, stylized facts may help to provide a sense of the differentiating characteristics of AI-intensive, innovative firms. In the search for such firms, the study employs two separate firm-level analyses drawing on two independent enterprise data sets that cover a broad range of industries and geographies. These cover two distinct segments from the population of innovative enterprises. The first covers medium and large publicly listed, R&D-expenditure leading firms. The second covers unicorn firms — successful start-ups that have achieved market valuations of approximately US$1 billion or more. Each of these two pools of firms is screened to identify firms that are likely to be among the leaders in AI technology development. The screens are based on published assessments from independent industry experts and each firm's membership in relevant industry bodies. The results are illustrative rather than strictly statistically representative.

The analysis here focuses on firms that have already achieved scale in the AI field. This matters for some dimensions of AI innovation

21 Citing the example of the Financial Stability Board, Robert Fay and Rohinton Medhora (2021) make a similar proposal for a Digital Stability Board that would operate with respect to regulation of the international digital economy more broadly.

including, for example, the costly development and training of original LLMs. While there is considerable potential for smaller firms to innovate and build AI application and service-provision businesses, scale may confer advantages in some fundamental areas of development (for example, foundation model development). Consideration of such a selection of large firms provides an opportunity to examine areas of concentration, which in turn may have implications for diffusion of some types of AI innovation.

AI Leaders among the Top Firms for R&D Expenditure Globally

The first assessment begins with consideration of the top 2,500 firms for R&D expenditure globally.[22] The analysis is based on data from the "EU Industrial R&D Investment Scoreboard," which is produced annually under the auspices of the European Commission (Grassano et al. 2022). In addition to R&D expenditure, this EU publication presents a range of performance indicators for each firm such as net sales, employment, capital expenditure and profitability. Each firm's country of registry and industry sector are also noted.[23] Across all fields, these firms invested collectively a total of US$1.3 trillion in R&D during 2021.[24] This represents about 86 percent of the estimated total global business expenditure on R&D that year,[25] and roughly half of the total global innovation expenditure from all sectors, including business, government, academia and non-profit institutions.[26]

In screening for leading AI-intensive firms among the top 2,500 R&D expenditure leaders, the analysis initially employs three screens: a listing of leading AI innovative firms from a widely read technology and business publication (*Enterprise Weekly*, *eWeek*, "Top 100+ Artificial Intelligence Companies 2023" listing, as of May 29, 2023[27]); firms included in Schwab's "AI Thematic Research" listing as of August 18, 2023[28]; and publicly listed firms in HSBC's Global Research equity coverage for AI firms in China.[29] AI intensity in a firm is taken here to mean that the firm's AI technology is expected to contribute significantly to the firm's own economic performance, and that the firm's AI innovation or application of AI innovation may have economically important implications for other firms in terms of their own performance (for example, whereby some may benefit due to inbound AI technology transfer or imitation, and others such as direct competitors may find themselves at a disadvantage). The three screens were selected based on two principal considerations: to tap into the firm-level expertise of a broad selection of professional industry analysts tracking firms in a fast-evolving sector to get a sense of their economic potential; and to ensure broad geographic coverage of leading AI firms across North America, Europe and Asia (including China).

Partial confirmation of the screening selection results was conducted by cross checking against AI industry group membership lists for the US-anchored Partnership on AI as of August 2023[30] and the China-anchored Artificial Intelligence Industry

22 R&D covers basic research, applied research and experimental development.

23 See Table 1 notes for more information on the industry classification employed by the EU study team.

24 See Nicola Grassano et al. (2022); an online overview is available at https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard#block-ecl-theme-page-title.

25 Ibid.

26 The World Bank provides data on R&D expenditure as a percentage of GDP and also provides GDP value (current US$). In 2020, this amounted to 2.63 percent of global GDP (latest year available, United Nations Educational, Scientific and Cultural Organization [UNESCO] data as reported by the World Bank). Global GDP was US$96.88 trillion in 2021 (World Bank data). R&D includes capital and current expenditures in the four main sectors: business enterprise, government, higher education and private non-profit. The value of global R&D from all sources totalled about US$2.55 trillion. This data is available from the World Bank at https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?name_desc=false (R&D as a percentage of GDP) and at https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?name_desc=false (GDP, value).

27 The current *eWeek* AI company listing is available at www.eweek.com/artificial-intelligence/ai-companies/. In the May 2023 edition employed for the present research, based on the expert opinion of the editorial team, a list of firms considered to be leading in each segment of their taxonomy of AI sector firms was assembled. The taxonomy was as follows: conversational AI, cybersecurity, education, enterprise majors, financial services, generative AI, giants, health-care AI, pioneers, retail and AI, robotic process automation, and visionaries. Per the *eWeek* taxonomy, "visionaries" are AI start-ups that are "closer to the edge, inventing the generative AI landscape in real time"; "pioneers" are forward-looking AI companies inventing and supporting the systems that are propelling AI development.

28 Schwab research data is available to clients at www.schwab.com/client-home.

29 HSBC Global Research references include Frank He (2023) for AI software and services, and Charlene Liu et al. (2023) for AI infrastructure.

30 According to the "About us" page on its website, the Partnership on AI is a non-profit partnership of academic, civil society, industry and media organizations creating solutions so that AI advances positive outcomes for people and society. The membership list is available via the Partnership on AI at https://partnershiponai.org/work/.

Alliance as of March 2020.[31] Both industry groupings have international membership. In six instances, firms from among the top 2,500 R&D innovators were selected for inclusion in the illustrative list of AI leaders based on their membership in one of these AI industry groups and their significant AI developments as discussed elsewhere in the trade press: Apple and Samsung due to their work on AI chips and consumer-facing AI innovation, as well as their scale; Synposis due to innovation in AI chip design software; Seagate due to AI storage innovation; China Telecom due to AI platform and LLM innovation; and Nokia for AI innovation in telecoms. (Further details of the screening are presented in Appendix 1, Table A.1, including a note on firms omitted due to data limitations in the EU listing of the top 2,500 R&D innovators.)

AI Leaders: Findings and Caveats

The screening process identifies 57 leading AI innovator firms, 56 of which are listed on major stock exchanges (see Table 1 and Appendix 1, Table A.1[32]). One striking result is the geographic concentration of these firms (see Table 2). Fully two-thirds of these firms are based in the United States. Among the other geographies, China accounted for less than one in seven of the listings and the European Union for less than one in 10. Collectively in 2021, these firms recorded R&D expenditure of US$264 billion, with some two-thirds of that expenditure by US-registered firms. Firms in China accounted for just under one-fifth of the total R&D expenditure and the EU for just one-sixteenth. Together, the 57 leading AI-intensive firms in the panel accounted for roughly one-tenth of global investment in R&D from all sources. While the data does not permit an assessment of the shares of panel firms' R&D with an explicit focus on AI, it is nonetheless clear that this panel of leading AI-intensive firms delivers research at a globally significant scale.

With respect to industry (see Table 2), the concentrations in the Industry Classification Benchmark (ICB) sectors "Technology Hardware & Equipment" and "Software & Computer Services" are in line with prior expectations. However, the ranking includes quite a few large and diversified corporations (for example, Alibaba, Alphabet, Apple, Baidu, Meta, Microsoft, Samsung and Sony) with notable product offerings beyond their listed industry, including other fields where AI applications might be employed (such as media or leisure goods). Alongside global multi-trillion US dollar behemoths such as Apple and Microsoft, a number of smaller firms with a particular focus on AI are included in the rankings (see Figure 1). One in three had a market capitalization of less than US$25 billion (Grassano et al. 2022). Thus, while large firms dominate the leading AI-intensive grouping (providing an upward shift to the averages), there is a significant subset of smaller firms that have gotten traction.

Table 3 provides comparisons between the leading AI-intensive firms, the remainder of the software and computer services firms (excluding the leading AI-intensive firms[33]), and the top 2,500 R&D firm sample as a whole. Considering the median scores for each group for the year 2021, the assessment reveals that the median leading AI-intensive firm is substantially larger than the median firm among the top 2,500 in absolute terms with respect to net sales (3.8x), employment (3.1x), R&D expenditure (8.4x), capital expenditure (capex) (3.3x), and operating profits (6.0x).[34] This is due in part to the presence of very large and diversified corporations in the AI rankings. Development of original AI models can be costly in terms of computing requirements and firm scale may provide an advantage in this regard. Larger firms may also have a broader range of in-house use cases to fuel AI demand. This is not to say that smaller AI intensive firms are excluded from the market. A number of smaller firms are proving competitive in adaptation of existing LLMs for particular uses and in developing AI-driven applications. In some

31 The Artificial Intelligence Industry Alliance (AIIA) website is available at http://aiiaorg.cn/index.php?m=alliance&c=index&a=structure. The version of the membership list employed in the present study was developed by the Center for Security and Emerging Technology (Luong and Arnold 2021). The authors describe the alliance as follows: "Through the AIIA, the Chinese government aims to foster collaboration among local governments, academic institutions, and companies. In some cases, the Chinese state uses the AIIA to 'pick winners,' choosing among favored companies in the AI industry to receive government subsidies" (ibid., 1).

32 For detailed firm-level performance indicators for these firms see Grassano et al. (2022), and the underlying data set available from the EU website at https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard#field_reportscoreboard.

33 As noted in Table 2, most, but not all, of the leading AI-intensive firms are in the ICB section "Software & Computer Services."

34 In this notation, "x" signifies "times." For example, net sales of the median leading AI-intensive firm are 3.8 times those of the median top 2,500 R&D firm.

cases, these smaller firms may compensate for lack of scale by drawing upon open-source inputs.

A further confirmation of the importance of scale to some segments of the AI sector can be found in Table 3 by considering the gap between the median leading AI-intensive firm and the median software and computer services firm (excluding leading AI-intensives). This gap is even larger than for the top 2,500 R&D firm sample as a whole. The median software and computer services firm (excluding the AI intensives) has lower net sales, lower employment, less capital expenditure and much lower operating profits than the median for the top 2,500 as a whole. Only with respect to R&D expenditure does the median software and computer service firm (excluding AI intensives) outperform the median firm among the top 2,500 sample as a whole. Indeed, the median R&D intensity (R&D expenditure relative to net sales) for both the leading AI-intensive firms and the remainder of the "Software & Computer Services" sector is much greater than for the top 2,500 sample as a whole (respectively 2.6x and 3.0x).

Caveats

The data employed in this assessment may be subject to certain biases. There are two important caveats: First, the EU team depends on the public availability of R&D expenditure data. Only firms that reveal this information are covered. This results in coverage primarily of publicly listed companies, though even among publicly listed firms the disclosures vary. Coverage is better for firms in the advanced economies, which tend to have better corporate disclosure of information on R&D. Thus, some potentially important AI innovators may be left off the European Union's ranking. According to the chosen AI-screening criteria, among large developers and innovative users of AI, some significant omissions include Amazon, Capital One, GE HealthCare, JD.com, McDonald's, Lowe's and Wipro. Second, some leading AI innovators are actually small in terms of the scale of R&D expenditure and thus may not meet the EU top 2,500 criteria, even if they are publicly listed and disclose R&D expenditure information. Among smaller publicly listed firms identified in the screens as leading in terms of AI technology but missing from the EU rankings one finds: Darktrace PLC, Innovative Eyewear Inc., Kore Group Holdings, Nano Dimension LTD, SoundHound AI Inc., and Xometry Inc. As a consequence of these caveats, this firm-level assessment may be considered as illustrative but not necessarily fully representative.

AI Leaders among the Unicorns

There is an active insurgency in the AI-intensive firm segment. A significant portion of the innovation in AI has been fuelled by start-ups challenging —

Table 1: Leading AI-Intensive Firms among Global R&D Expenditure Leaders, Publicly Listed, 2021

Company	Country	Industry (ICB Sector)	Company	Country	Industry (ICB Sector)
Accenture	Ireland	Support Services	Intuit	United States	Software & Computer Services
Adobe	United States	Software & Computer Services	Medtronic Public Limited	Ireland	Health Care Equipment & Services
Alibaba Group Holding	China	Software & Computer Services	Meta	United States	Software & Computer Services
Alphabet	United States	Software & Computer Services	Microsoft	United States	Software & Computer Services
Altair Engineering	United States	Software & Computer Services	NetEase	China	Software & Computer Services
Alteryx	United States	Software & Computer Services	NICE	Israel	Software & Computer Services
Ambarella	United States	Technology Hardware & Equipment	Nokia	Finland	Technology Hardware & Equipment
Apple	United States	Technology Hardware & Equipment	Nvidia	United States	Technology Hardware & Equipment

Table 1 (continued)

Company	Country	Industry (ICB Sector)
Baidu	China	Software & Computer Services
Broadcom	United States	Technology Hardware & Equipment
Butterfly Network	United States	Health Care Equipment & Services
C3.ai	United States	Software & Computer Services
Cambricon Technologies	China	Technology Hardware & Equipment
Cerence	United States	Software & Computer Services
Ceva	United States	Mobile Telecommunications
Check Point Software Technologies	Israel	Software & Computer Services
China Telecom	China	Technology Hardware & Equipment
Coherent	United States	Electronic & Electrical Equipment
CrowdStrike Holdings	United States	Software & Computer Services
Dell Technologies	United States	Technology Hardware & Equipment
Duolingo	United States	Software & Computer Services
Fortinet	United States	Software & Computer Services
Hewlett Packard Enterprise	United States	Software & Computer Services
Huawei Investment & Holding	China	Technology Hardware & Equipment
IBM	United States	Software & Computer Services
iFlytek	China	Software & Computer Services
Informatica	United States	Software & Computer Services
Infosys	India	Software & Computer Services
Intel	United States	Technology Hardware & Equipment
Oracle	United States	Software & Computer Services
Palo Alto Networks	United States	Software & Computer Services
Pegasystems	United States	Software & Computer Services
Rockwell Automation	United States	Industrial Engineering
Salesforce	United States	Software & Computer Services
Samsung Electronics	South Korea	Electronic & Electrical Equipment
SAP	Germany	Software & Computer Services
Seagate Technology	Ireland	Technology Hardware & Equipment
ServiceNow	United States	Software & Computer Services
Shutterstock	United States	Media
Snowflake	United States	Software & Computer Services
Sony	Japan	Leisure Goods
SS&C Technologies	United States	Software & Computer Services
Stryker	United States	Health Care Equipment & Services
Synaptics	United States	Technology Hardware & Equipment
Synopsys	United States	Software & Computer Services
Tencent	China	Software & Computer Services
Thomson Reuters	Canada	Support Services
UiPath	United States	Software & Computer Services
Zscaler	United States	Software & Computer Services

Source: Grassano et al. (2022); author's tabulations. The underlying data set is available from the EU website at https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard#field_reportscoreboard.

Notes: Huawei Investment & Holding is employee-owned. Also, the ICB taxonomy is employed here. The firm FTSE Russell manages the taxonomy. For details, see www.lseg.com/en/ftse-russell/industry-classification-benchmark-icb and Grassano et al. (2022, 11).

Table 2: Counts of Top Publicly Listed AI Innovator Firms, by Country of Registry and Sector, 2021

Country		Industry (ICB Sector)	
Canada	1	Electronic & Electrical Equipment	2
China	8	Health Care Equipment & Services	3
Finland	1	Industrial Engineering	1
Germany	1	Leisure Goods	1
India	1	Media	1
Ireland	3	Mobile Telecommunications	1
Israel	2	Software & Computer Services	34
Japan	1	Support Services	2
South Korea	1	Technology Hardware & Equipment	12
United States	38		
Total AI innovator firms	**57**	**Total AI innovator firms**	**57**
Of which registered in EU member countries	**5**		

Source and *Notes:* Refer to Table 1 source and notes.

and then in some cases eventually collaborating with — the larger incumbents. Among the most well-known, for example, are OpenAI (developer of the ChatGPT model, now affiliated with Microsoft) and ByteDance (developer of TikTok and a government-approved LLM called Yunque; ByteDance is a private firm with a public listing pending). The most successful AI-intensive start-ups, such as these two, can grow to become unicorns many times over (be valued at many US$ billions).

In this second firm-level assessment, the analysis shifts to consider the global database of 1,220 unicorns developed by CB Insights, a list covering firms from a broad range of sectors. By cross-referencing this database against the roster of AI leaders published by *eWeek* (Maguire 2023), the analysis develops a working list of top AI-intensive unicorns (see Table 4). Based on references in the literature, the analysis added two further start-ups. The first is Epic Games, a US-based unicorn affiliated with Tencent. This firm maintains innovative transparency provisions for content management. Generative AI content is welcomed from vendors on the firm's Unreal Engine Marketplace, but must be labelled as such. Vendors may also exclude their content from use by others in AI training (Epic Games 2023). The second additional start-up is Zhipu AI, an innovative start-up selling access to its AI models as a service. Zhipu AI also has a LLM that received government approval in China in August 2023 (Liu et al. 2023).

Unicorns: Findings and Caveats

One striking characteristic of this list of 22 unicorns is the geographic concentration. All but four of these unicorns are US-based firms, the others being based in China (two) and the United Kingdom (two). Looking a bit closer, the extent of the geographic concentration is revealed. Only a few cities within these three countries actually host these unicorns (see Figure 2). This view found 10 unicorns emerging in the San Francisco-Mountain View-San Jose corridor of California. Another five are based in New York City, with Boston, Massachusetts, Cary, North Carolina, and Austin, Texas, accounting for the remaining US entries on the list. London accounts for two and Beijing for two. In terms of sector, nearly two-thirds (14) of the unicorns are focused on enterprise technology. Three are concerned with consumer and retail applications, three with media and entertainment, and two with health care and life sciences. Most of the current AI leaders among the unicorns are focused on products for businesses (business-to-business [B2B]), even though some of the B2B products will be employed in consumer-facing applications. A few are delivering direct-to-consumer products such as TikTok (ByteDance), Fortnite (Epic Games) or ChatGPT and DALL-E (OpenAI).

Table 3: Counts and Median Scores for the Group of Leading AI-Intensive Firms versus Other Groupings, 2021

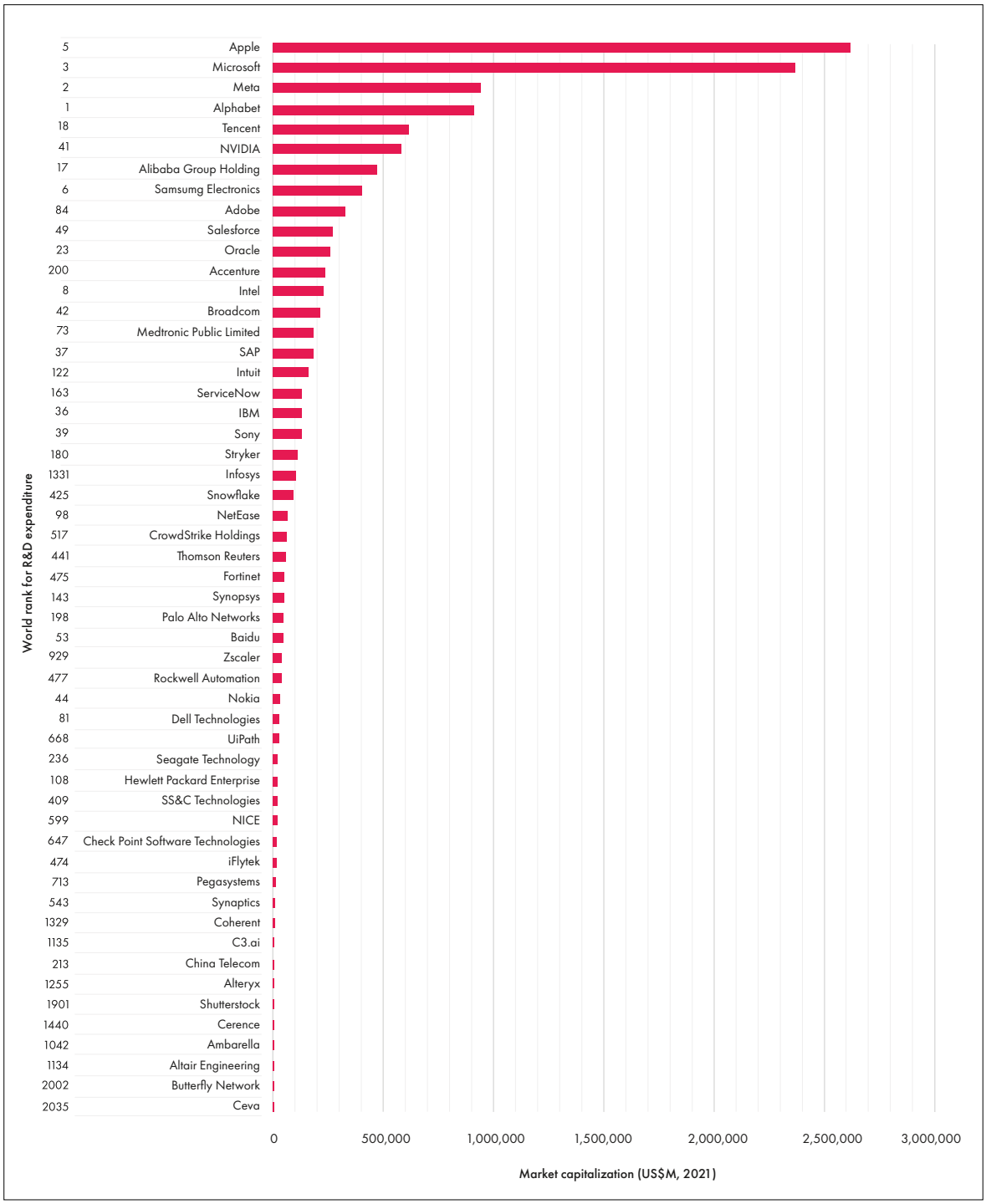
	Counts				Median Scores					
	Number of firms	Number of countries	Number of regions	Number of industry (ICB) sector names	Median world rank	R&D 2021 (US$M)	R&D one-year growth (%)	Net sales (US$M)	Net sales one-year growth (%)	R&D intensity (%)
AI-intensive firms	57	10	5	9	200	1,168.1	18.3	10,061.7	18.0	16.9
Software and computer services firms (excluding AI-intensive)	302	23	5	1	1143	156.7	22.7	782.5	21.8	19.3
Top 2,500 R&D firms (full sample)	2,500	41	5	38	1251	139.4	15.7	2,627.2	16.9	6.4

	Median Scores									
	Capex (US$M)	Capex one-year growth (%)	Capex intensity (%)	Operating profits (US$M)	Operating profits one-year growth (%)	Profitability (%)	Employees	Employees, one-year growth (%)	Market capitalization (US$M)	Market capitalization one-year growth (%)
AI-intensive firms	341.4	5.6	3.1	1,297.6	26.8	14.0	23,437	11.3	53,759.0	36.7
Software and computer services firms (excluding AI-intensive)	18.2	11.3	2.0	4.6	12.0	1.2	3,610	15.0	5,682.4	17.2
Top 2,500 R&D firms (full sample)	104.3	13.2	4.1	216.1	21.1	8.0	7,522	5.3	5,200.4	26.6

Source: Grassano et al. (2022); underlying data set is available from the EU website at https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard#field_reportscoreboard; author's tabulations. US$ figures are converted from euros using the US Federal Reserve annual exchange rate (G.5A), available at www.federalreserve.gov/releases/g5a/current/.

Note: As defined in Grassano et al. (2022), the regional taxonomy includes China, the European Union, Japan, the United States, and the rest of the world.

Figure 1: Top Publicly Listed AI-Intensive Firms with Respect to R&D Expenditure, Ranked by Market Capitalization



Source: Grassano et al. (2022); underlying data set is available from the EU website at https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard#field_reportscoreboard; author's tabulations.

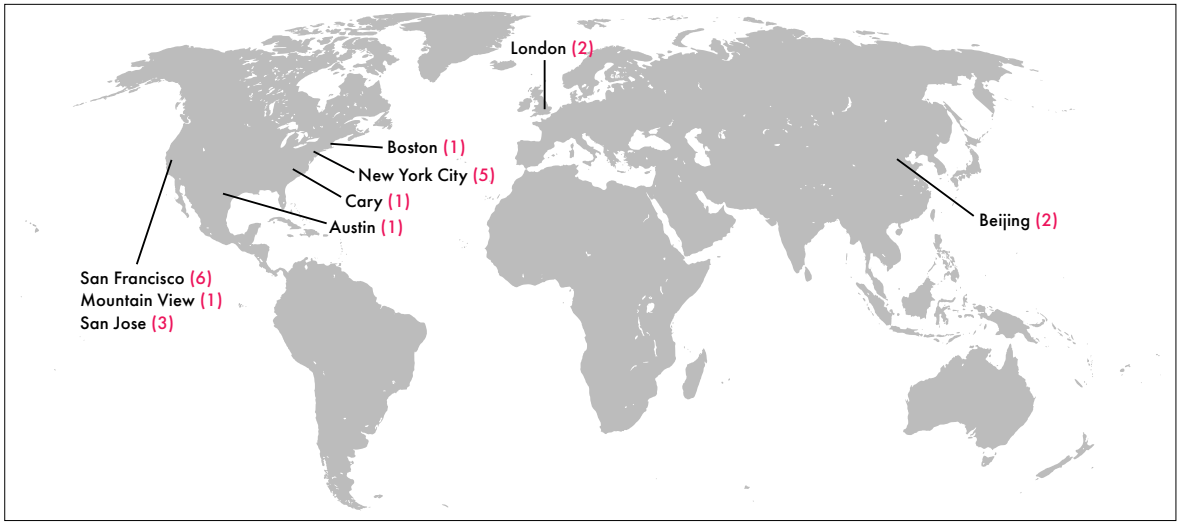
Note: The EU database does not include market capitalization data for Cambricon Technologies, Duolingo, Huawei Investment & Holdings or Informatica.

The geographic concentration may be supported by the availability of venture capital (VC) in some of these areas (see Table 4). VC providers often not only supply investment funds, but also mobilize expertise to help start-ups network and enhance their strategy and operations. The combination of ample investment funding and advisory support may provide a draw to specific geographies. Other draws might include availability of skilled staff and access to complementary academic research. Interestingly, a review of 50 generative AI start-ups by VC firm Andreessen Horowitz (Moore 2023) found that nearly half had managed to bootstrap their launch without outside investment funding. AI start-up costs can vary dramatically depending on whether a firm is developing and training a proprietary model (such firms raised an average of US$98 million); fine-tuning an existing model (such firms raised an average of US$20 million) or improving the user interface for an existing model (such firms raised an average of US$9 million). It is notable that six of the 22 unicorns reportedly have received investment from large AI-intensive firms such as Google (Alphabet, four), Microsoft (one) and Tencent (one). As with VC firms, such investment relationships can be a source of capital and industry knowledge, but may offer additional opportunities for supply-chain integration and technology transfer. They may also pose risks by potentially reducing competition in cases where the relationship leads to an outright acquisition instead of an initial public offering (for example, see Ederer and Pellegrino 2023).

Caveats

As with the previous assessment, there are a number of caveats that apply here. First, information on the status of start-ups may be difficult to obtain in some markets and some potentially noteworthy AI start-ups may be missed (for example, due to underestimation of a start-up's valuation). Second, even where a unicorn is identified, it may be that there was insufficient public information on important AI developments at the firm and that the unicorn was therefore not flagged as an AI innovator. Third, the analysis depended on a limited set of screens covering privately held AI start-ups; it may be that due to a gap in coverage in the screens an AI-innovator unicorn was omitted. As a consequence of these caveats, this firm-level assessment may be considered as illustrative but not necessarily fully representative. In addition, it should be noted that unicorns are exceptional start-ups that have achieved scale. The availability of desktop AI development tools like Pytorch (developed by Meta, now maintained by Linus Foundation).

Figure 2: City Locations and Number of AI-Leader Unicorn Firms, October 19, 2023



Sources: CB Insights (2023a), Maguire (2023), Liu et al. (2023), Epic Games (2023), San Jose (2023); author's tabulations and map markup, using map from https://commons.wikimedia.org/wiki/File:World_map_blank_gmt.png.

Table 4: AI-Intensive Unicorns (Private Start-Up Firms Valued at US$1 Billion or More), October 19, 2023

Company	Valuation (US$B)	Date Joined	Country	City	Industry	Key Investors
Adept	1.0	March 14, 2023	United States	San Francisco	Enterprise Tech	Greylock Partners, Addition, M12
AlphaSense	2.5	June 15, 2022	United States	New York	Enterprise Tech	Viking Global Investors, GS Growth, BlackRock; **Google**
Anthropic	4.4	February 3, 2023	United States	San Francisco	Enterprise Tech	**Google**
Automation Anywhere	6.8	July 2, 2018	United States	San Jose	Enterprise Tech	General Atlantic, Goldman Sachs, New Enterprise Associates
Bloomreach	2.2	February 23, 2022	United States	Mountain View	Consumer & Retail	Bain Capital Ventures, Sixth Street Growth, Lightspeed Venture Partners
ByteDance	225.0	April 7, 2017	China	Beijing	Media & Entertainment	Sequoia Capital China, SIG Asia Investments, Sina Weibo, SoftBank Group
Databricks	43.0	February 5, 2019	United States	San Francisco	Enterprise Tech	Andreessen Horowitz, New Enterprise Associates, Battery Ventures
Dataiku	3.7	December 4, 2019	United States	New York	Enterprise Tech	Alven Capital, FirstMark Capital, capitalG
DataRobot	6.3	July 29, 2019	United States	Boston	Enterprise Tech	New Enterprise Associates, Accomplice, IA Ventures
Hugging Face	4.5	May 9, 2022	United States	New York	Enterprise Tech	Betaworks Ventures, Addition, Lux Capital
insitro	2.4	March 15, 2021	United States	South San Francisco	Healthcare & Life Sciences	Foresite Capital, ARCH Venture Partners, Third Rock Ventures
Jasper	1.5	October 17, 2022	United States	Austin	Enterprise Tech	Foundation Capital, Institutional Venture Partners, Founders Capital
OpenAI	29.0	July 22, 2019	United States	San Francisco	Enterprise Tech	Khosla Ventures, **Microsoft**
Owkin	1.0	November 18, 2021	United States	New York	Healthcare & Life Sciences	Google Ventures, Cathay Innovation, NJF Capital, **Sanofi**
Runway	1.5	May 4, 2023	United States	New York	Media & Entertainment	Lux Capital, Compound, Amplify Partners
Signifyd	1.3	April 15, 2021	United States	San Jose	Consumer & Retail	Menlo Ventures, Resolute Ventures, IA Ventures
Stability AI	1.0	October 5, 2022	United Kingdom	London	Enterprise Tech	Lightspeed Venture Partners, Coatue Management
Standard AI	1.0	February 17, 2021	United States	San Francisco	Consumer & Retail	CRV, Y Combinator, Initialized Capital
Synthesia	1.0	June 13, 2023	United Kingdom	London	Enterprise Tech	Google Ventures, Kleiner Perkins Caufield & Byers, FirstMark Capital
Vectra AI	1.2	April 29, 2021	United States	San Jose	Enterprise Tech	IA Ventures, Khosla Ventures, AME Cloud Ventures
Other notable examples						
Epic Games	31.5	October 26, 2018	United States	Cary	Media & Entertainment	Tencent Holdings, KKR, Smash Ventures
Zhipu AI	1.0	September 20, 2023	China	Beijing	Enterprise Tech	Qiming Venture Partners, Legend Capital, Jiangmen Venture Capital, also *Meituan*

Sources: CB Insights (2023a); Epic Games (2023); and the various company websites, except for "key investors," which are from CB Insights (2023a) with **bolded entries** from Maguire (2023) and an *italicized entry* from Liu et al. (2023).

Note: "Date joined" refers to the date CB Insights recognized each firm for inclusion in the "Global Unicorn Club."

Regulatory Developments

The ongoing breakthrough innovation in AI is taking place as regulators race to keep up. Domestic efforts alone will not suffice in an environment where international access to AI models, data sets and system users is readily achieved. Consultations are ongoing via the G7 and G20, as well as at international organizations ranging from the OECD and UNESCO to the International Telecommunications Union and the World Intellectual Property Organization (WIPO), among many others.

This section considers the leading areas of regulatory development, as well as areas where additional facilitation or improved alignment may be required. Where points of divergence are emerging, there may be potential benefits for diffusion of AI technology from having reinforcement of international coordination and governance. A centrally anchored approach may be needed, for example, in order to ensure worldwide alignment on basic elements of safety, reliability and trustworthiness.

What Does Current International Monitoring of AI Regulation Tell Us?

With such a dynamic regulatory environment, it is fortunate that some observers are monitoring developments. To get a sense of the areas of focus for policy makers and regulators, the analysis now turns to two sources: the OECD; and the Digital Policy Alert (DPA), an initiative of the St. Gallen Endowment, which has its origins in the University of St. Gallen but has since been spun off and now operates with an international virtual structure. Updates from each source are considered in this section.

OECD.AI Policy Observatory

The OECD tracks AI developments across countries representing most of the global economy via its OECD.AI Policy Observatory. Drawing on resources of the OECD secretariat, member states and a network of more than 250 AI experts from other partner and stakeholder groups, the OECD monitors national AI strategies and regulatory instruments. These policy developments are considered in relation to the OECD AI Principles.[35] The result is a publicly consultable database, offering summary information and links to the original sources. This data is available on an annual basis with somewhat of a lag. At the time of writing, the bulk of the OECD coverage begins in 2017 and ends in 2021.

To provide a sense of the dynamics in policy formation, Table 5 reports on the number of policy initiatives for each type of policy instrument tracked in the OECD system. These are simple counts of actions, unweighted by the scale of impacts or any other factor. Among the sample countries hosting the leading AI-intensive innovators and AI unicorns, there is some variation in the scale of activity (see Table 5, Part 1). The total counts range from 23 to 116 with a median score of 43.5. For comparison, the assessment also considers a set of non-sample countries, with examples from regions not covered by the AI leader sample (see Table 5, Part 2). The non-sample countries are Brazil, Indonesia, Singapore, South Africa and Vietnam. Among these countries, the counts range from two to 37.

The United States was the most active of the countries covered with 116 initiatives tracked, followed by the United Kingdom at 91. The supranational EU institutions delivered 80 actions, which were complemented by national-level initiatives. Among the three EU members covered, Finland had just 23 policy actions at the national level while Germany and Ireland had 61 and 56, respectively.[36] Among the sample countries, India, Japan and Korea had moderate levels of activity at 35, 36 and 51 actions each, respectively. Canada, China and Israel had somewhat lower levels of policy activity during this period at 27, 26 and 26, respectively. Among the non-sample countries, Singapore and Brazil delivered levels of policy activity within the range for the sample countries. Indonesia, South Africa and Vietnam had much lower levels of activity.

35 See Appendix 2 and an overview at https://oecd.ai/en/ai-principles.

36 Germany (15) and Ireland (11) undertook much more activity relating to grants than Finland (two). In addition, Ireland engaged in a substantial amount of activity with respect to AI skills and education (10), significantly exceeding the levels in Germany (one) or Finland (zero), as well as every other country in the sample. Meanwhile, Germany racked up four activities related to data access and sharing while Ireland and Finland abstained (zero and zero, respectively).

The top three policy actions among the sample countries were:

- National strategies, agendas and plans with a median score among the sample countries of seven actions. According to OECD.AI (2021), "Strategies articulate the government's vision regarding the contribution of STI [Science, Technology and Industry] to a country's social and economic development. They set priorities for public investment in STI and identify the focus of government reforms, for instance in areas such as funding of public research and promoting business innovation."
- Emerging AI-related regulation with a median score among the sample countries of five actions. According to the OECD.AI this category refers to "laws, rules, directives or other policies made by a public authority on the development or use of new technologies (e.g. artificial intelligence, neuro-technology and gene-editing)."[37]
- Public consultations of stakeholders or experts. OECD.AI (ibid.) defines such instruments as "Programmes allowing non-government actors (e.g. the research community, business, civil society, regional and local governments) to express their views or provide expert advice that inform policy-making processes."[38]

Both Brazil and Singapore had levels of activity for the category "AI use in the public sector" well above the median for the sample countries. They also had levels of activity for the category "Public consultations of stakeholders or experts" well below the median for the sample countries. Singapore was well above the median sample country score for the category "Standards and certification for technology development and adoption" (a category where a majority of the sample countries had no actions at all). As for Indonesia, South Africa and Vietnam, they substantially lagged the sample country median scores for the categories "Emerging AI- related regulation and Public consultation of stakeholders or experts."

Interestingly, among the 707 policy initiatives undertaken across the sample and non-sample countries and summarized in Table 5, two terms came up fairly consistently, "innovation" and "transparency." There were references to both for nearly all countries. The only exceptions were South Africa and Vietnam, which lacked references to transparency in the descriptions of the instruments as recorded in the OECD database for the period. Among the sample countries, Ireland, Germany and the European Union had the largest number of policy initiatives with mentions of innovation. Canada and Japan had the fewest initiatives referencing innovation, with four each. Other sample countries fell in the range of five to 13 innovation activity mentions each. Brazil and Singapore had numbers of mentions of innovation that fell in the range for the sample countries.

Transparency was also a recurrent theme. Across the countries shown, the policy initiatives concerning transparency varied widely in their scope ranging from preparatory and planning purposes to regulatory actions and implementation of legislation. For example, among the 40 US policy initiatives identified in the OECD database were actions on the process for AI policy formation (for example, see NIST 2019) and the actual operation of algorithms (see, for example, Office of Management and Budget 2019), among other issues. Along with the United States, South Korea, the European Union, Japan and Israel all had above average levels of activity concerning transparency. Sample countries with more moderate levels of activity around transparency included Germany, India, Canada, China, the United Kingdom and Ireland. Finland benefited from EU initiatives, but lagged behind at the national level. Brazil and Singapore again had numbers of mentions that fell in the range for sample countries.

Findings from Analysis of OECD AI Policy Tracking

Across the countries considered in this section, the prevalence of actions toward development of national AI strategies, agendas and plans is encouraging, especially when paired with the also-prevalent addition of measures for public consultation of stakeholders and experts. It may be that this combination will yield more strategic and pragmatic regulatory outcomes than would otherwise be the case. As of 2021, every country covered here except South Africa undertook initiatives in both areas. Moreover, it would seem plausible that efforts to improve transparency — in regulatory processes and in

37 See https://oecd.ai/en/dashboards/policy-instruments/Emerging_technology_regulation.

38 See https://oecd.ai/en/dashboards/policy-instruments/Public_consultations_of_stakeholders_or_experts.

the functioning of AI products — would enable stakeholders and experts to provide better-informed inputs to support development of national AI regulatory and innovation systems. Similarly, openness and transparency in the system would seem to have the potential to pair well with the development of policy actions to encourage AI innovation, another consistent theme in most of the countries considered here.[39] Although it is beyond the scope of regulations covered in this data set, competition policy (openness to market entry and new competitors) could also play an important role in promoting firm-level innovation (Kiriyama 2012; Christensen 2016).

Overall, the policy initiatives highlighted in this section would seem well pitched to improve coherence and effectiveness of national AI policy, potentially encouraging AI innovation and its diffusion in domestic markets. Where due account is taken of international standards and practices applied in trade partners, and where international regulatory cooperation is pursued, it is possible that cross-border

Table 5, Part 1: Counts of Policy Initiatives as of 2021 in Relation to AI in Countries Hosting Leading AI-Innovator Firms and Unicorns

Policy Instrument Type	Canada	China	European Union	Finland	Germany	India	Ireland	Israel	Japan	South Korea	United Kingdom	United States	Median	Average
AI coordination and/or monitoring bodies	1	1	3	2	2	1	2	2	0	1	2	11	2.0	2.3
AI computing and research infrastructure	0	0	2	1	3	2	4	3	2	5	3	6	2.5	2.6
AI skills and education	0	0	0	0	1	2	10	0	2	0	1	1	1.0	1.5
AI use in the public sector	1	0	0	0	1	2	5	4	0	0	4	11	1.0	2.3
Centres of excellence grants	0	0	0	0	3	4	2	0	0	3	1	2	0.5	1.3
Data access and sharing	0	0	4	0	4	1	0	2	2	3	1	1	1.0	1.5
Emerging AI-related regulation	3	10	20	2	5	4	2	3	6	5	21	27	5.0	9.0
Equity financing	0	0	1	0	0	0	2	0	0	1	1	0	0.0	0.4
Fellowships and postgraduate loans and scholarships	0	0	2	0	0	0	0	1	0	1	5	9	0.0	1.5
Grants for business R&D and innovation	0	0	7	1	2	0	0	3	2	3	0	0	0.5	1.5
Indirect financial support	0	0	0	0	0	0	0	0	0	1	1	0	0.0	0.2
Institutional funding for public research	1	1	0	0	0	0	3	2	0	0	0	3	0.0	0.8
Knowledge transfers and business advisory services	0	0	2	1	1	1	2	0	1	2	2	2	1.0	1.2
Labour market policies	0	0	0	0	0	0	1	0	0	0	1	0	0.0	0.2
Labour mobility regulation and incentives	0	0	0	0	0	0	0	0	0	1	2	2	0.0	0.4

39 For an example of the role of transparency and consultation in regulatory reform drawing on an OECD case study of Israel, see Charles Tsai et al. (2011, 18–23).

Table 5, Part 1 (continued)

Policy Instrument Type	Canada	China	European Union	Finland	Germany	India	Ireland	Israel	Japan	South Korea	United Kingdom	United States	Median	Average
National strategies, agendas and plans	4	9	14	6	6	5	2	2	8	11	13	14	7.0	7.8
Networking and collaborative platforms	4	1	6	1	11	3	6	1	3	4	8	5	4.0	4.4
Procurement programs for AI R&D and innovation	1	0	1	2	0	1	1	1	0	2	4	0	1.0	1.1
Project grants for public research	2	0	5	1	10	0	9	1	1	4	3	5	2.5	3.4
Public awareness campaigns and civic participation activities	1	0	2	0	3	1	1	0	0	0	2	4	1.0	1.2
Public consultations of stakeholders or experts	6	2	8	5	5	4	3	1	5	2	12	6	5.0	4.9
Regulatory oversight and ethical advice bodies	1	0	2	1	3	4	0	0	3	1	4	5	1.5	2.0
Standards and certification for technology development and adoption	2	1	1	0	0	0	1	0	0	0	0	2	0.0	0.6
Science and innovation challenges, prizes and awards	0	1	0	0	1	0	0	0	1	1	0	0	0.0	0.3
Total count	**27**	**26**	**80**	**23**	**61**	**35**	**56**	**26**	**36**	**51**	**91**	**116**	**43.5**	**52.3**
Memo Items														
Policy initiatives in the OECD.AI policy database that mention "innovation" in the objective description (counts)	4	5	18	5	18	6	38	7	4	11	11	13	9.0	11.7
Share of initiatives tagged for having a mention of "innovation" in the objective description (percentage)	*14.8*	*19.2*	*22.5*	*21.7*	*29.5*	*17.1*	*67.9*	*26.9*	*11.1*	*21.6*	*12.1*	*11.2*	*20.4*	*23.0*
Policy initiatives in the OECD.AI policy database addressing transparency issues (e.g., in policy formation and regulatory processes or in the operation of algorithms)	9	9	21	2	12	11	7	17	20	24	9	40	11.5	15.1
Share of initiatives tagged in relation to transparency (percentage)	*33.3*	*34.6*	*26.3*	*8.7*	*19.7*	*31.4*	*12.5*	*65.4*	*55.6*	*47.1*	*9.9*	*34.5*	*32.4*	*31.6*

Sources: OECD.AI (2021) and author's tabulations.

Notes: The data covers the period from 2017 to 2021. The table presents simple counts of AI policy instruments with no attempt to standardize the units or control for size of impacts. Where there is an even number of observations, the median is calculated as the average of the two middle scores.

Table 5, Part 2: Counts of Policy Initiatives as of 2021 in Relation to AI in an Illustrative Group of Other Countries

	Sample Countries	Non-sample Countries				
Policy Instrument Type	Median	Brazil	Indonesia	Singapore	South Africa	Vietnam
AI coordination and/or monitoring bodies	2.0	1	0	0	0	0
AI computing and research infrastructure	2.5	0	0	0	0	1
AI skills and education	1.0	1	0	0	0	0
AI use in the public sector	1.0	13	0	6	0	0
Centres of excellence grants	0.5	1	0	0	0	0
Data access and sharing	1.0	0	0	1	0	0
Emerging AI-related regulation	5.0	2	0	6	0	1
Equity financing	0.0	0	0	0	0	0
Fellowships and postgraduate loans and scholarships	0.0	0	0	0	0	0
Grants for business R&D and innovation	0.5	0	0	1	0	0
Indirect financial support	0.0	0	0	0	0	0
Institutional funding for public research	0.0	1	0	1	0	0
Knowledge transfers and business advisory services	1.0	1	0	2	0	0
Labour market policies	0.0	0	0	0	0	0
Labour mobility regulation and incentives	0.0	0	0	0	0	0
National strategies, agendas and plans	7.0	5	1	9	0	2
Networking and collaborative platforms	4.0	0	0	2	1	0
Procurement programs for AI R&D and innovation	1.0	0	0	0	0	1
Project grants for public research	2.5	1	0	1	0	1
Public awareness campaigns and civic participation activities	1.0	0	0	2	0	1
Public consultations of stakeholders or experts	5.0	2	1	1	1	1
Regulatory oversight and ethical advice bodies	1.5	0	0	1	1	0
Standards and certification for technology development and adoption	0.0	1	0	4	0	0
Science and innovation challenges, prizes and awards	0.0	0	0	0	0	0
Total count	**43.5**	**29**	**2**	**37**	**3**	**8**
Memo Items						
Policy initiatives in the OECD.AI policy database that mention "innovation" in the objective description	9.0	19	2	11	1	2
Share of initiatives tagged for having a mention of "innovation" in the objective description (percentage)	*20.4*	*65.5*	*100.0*	*29.7*	*33.3*	*25.0*
Policy initiatives in the OECD.AI policy database addressing transparency issues (e.g., in policy formation and regulatory processes or in the operation of algorithms)	11.5	11	2	10	0	0
Share of initiatives tagged in relation to transparency (percentage)	*32.4*	*37.9*	*100.0*	*27.0*	*0.0*	*0.0*

Sources and *Notes:* See Table 5, Part 1, sources and notes.

impediments to diffusion of AI innovation may also be addressed as part of these efforts.[40]

DPA: Machine Learning and AI Policy Activity

In order to get a better sense of the recent policy dynamics around the acceleration in AI, the analysis turns to a more current resource for tracking AI policy activity. This is DPA, an initiative of the St. Gallen Endowment for Prosperity through Trade. It covers policy developments in G20 countries, EU member states and Switzerland. The sample employed for the present analysis is for actions relevant to machine learning[41] and AI. The actions tracked include laws, orders, standards and guidelines regulating the development and use of AI systems, as well as related regulatory actions and policy development work. Activities may focus on one or more policies and a single policy may be the object of one or more activities over time. The database is updated in an ongoing manner with the support of customized software.

The structure of the DPA database is conducive to consideration of policy activity over time for recent years starting in 2020. Table 6 provides an illustration of the acceleration in policy activity between two periods, 2020–2021 and 2022–November 2023. From the initial period, all of the sample countries hosting leading AI-intensive firms were already engaged in machine learning and AI policy activities. The United States led the group with 15 incidents of policy activity, followed by the European Union (10), the United Kingdom (eight) and China (seven). A few international country groupings also took some steps in the first two years covered here (2020–2021). In the second period, from 2022 to November 2023, the volume of activity accelerated by 4.2 times overall. The leading AI-intensive firm host countries all stepped up policy activity, including the United States (to 99 activities), China (to 26), the European Union (to 20) and the United Kingdom (to 20). The number of actions across international borders also ramped up, from five in the initial two years to 37 in the period from 2022 to November 2023.

Each of these international actions engaged one or more countries from the sample.

The subject matter covered increased in scope and intensity (see Table 7). During 2020–2021, 12 subject areas were tackled. In 2022–2023, this rose to 30. In both periods, "Algorithm design and technical standards" exhibited the most activity. "Data protection regulation" activity rose dramatically from the first period to the second. Also during the second period, "Cyber security regulation," "Content moderation regulation," "Intellectual property (copyright and patents)" and "Consumer protection regulation" all rose to fill out the top ranks of policy areas. Moreover, the increased volume of policy activity led to substantive results. Activities for policies adopted rose from 40 during the first biennium, to 114 during the second. A further 35 actions concerned policies in force during 2022–2023. In addition, the pipeline of policy activity points to a continued high volume of activity going forward. During 2022–2023, some 45 instruments were at some point in the consultation process and 80 were under deliberation. Among the leading issues for activities concerning policy instruments under deliberation, "Algorithm design and technical standards" remains in first place and "Data protection regulation" places a strong second.

Findings from Analysis of DPA Tracking

The DPA tracking highlights the responsiveness of policy makers to the acceleration in AI innovation, with the frequency of policy initiatives increasing as well as the country coverage. Some of the subject areas frequently targeted, such as technical standards and IP rights, can have an influence on diffusion of technology across borders. Alignment in regulation in these areas can facilitate trade in products and services by permitting developers to aim for a more uniform product with less tailoring required, potentially also reducing the burden of testing and certification where required. The increased coverage of protection of IP rights and data protection may also enable developers to sell AI products into an expanded range of markets (for example, if the reforms enable developers to better protect their products from abuses or if the reforms reduce uncertainty with respect to liability). Also, concerning regulatory alignment, it is encouraging to see the growing number of country groupings taking joint policy initiatives, often including the major economies.

40 For more on this perspective of regulatory reform, see the OECD efficient regulation principles for market openness (Tsai et al., 2011, 18, box 1) and the detailed discussion of the application of these principles in the case of Israel (ibid., 18–39).

41 Machine learning involves use of a model trained and refined on large data sets to classify information, make predictions and generate content. It enables computers to learn without being explicitly programmed.

Table 6: Dynamics of Recent Machine Learning and AI Policy Developments, January 2020–November 2023 (Counts)

2020–2021	
Country or Group of Countries	Policy Activity
—	
Australia	3
—	
Brazil	2
Canada	2
China	7
—	
European Union	10
—	
Germany	3
—	
Hong Kong	1
—	
India	2
Indonesia	1
Italy	1
—	
—	
—	
—	
—	
Russia	1
—	
—	
—	
South Korea	4
Spain	1
Switzerland	1
Taiwan	1
Türkiye	2
—	
—	
United Kingdom	8
United States	15
Australia, European Union, India, Japan, Mexico, New Zealand, Singapore, South Korea, United Kingdom, United States	1
Canada, United Kingdom, United States	1
Chile, New Zealand, Singapore, South Korea	1
UNESCO membership	2

2022–2023	
Country or Group of Countries	Policy Activity
Argentina	5
Australia	6
Austria	1
Brazil	7
Canada	9
China	26
Denmark	1
European Union	20
France	6
Germany	9
Greece	1
—	
Hungary	1
India	3
Indonesia	1
Italy	4
Japan	8
Netherlands	3
New Zealand	2
Peru	2
Poland	1
Russia	1
Saudi Arabia	1
Singapore	4
South Africa	1
South Korea	8
Spain	5
Switzerland	2
—	
—	
Ukraine	1
United Arab Emirates	1
United Kingdom	20
United States	99
—	
—	
—	
—	

Table 6 (continued)

2020–2021		2022–2023	
Country or Group of Countries	Policy Activity	Country or Group of Countries	Policy Activity
—		Albania, Argentina, Brazil, Chile, China, Colombia, Ecuador, Egypt, Estonia, Ethiopia, Finland, France, Germany, Guyana, India, Israel, Italy, Japan, Kenya, Mexico, Netherlands, New Zealand, Pakistan, Peru, Portugal, Russia, Saudi Arabia, Senegal, Singapore, South Africa, South Korea, Spain, Suriname, Switzerland, Trinidad & Tobago, United Arab Emirates, United Kingdom, United States, Zimbabwe	1
—		Ibero-American Network: Andorra, Argentina, Brazil, Cape Verde, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Portugal, Sao Tome & Principe, Spain, Uruguay	1
—		Argentina, Australia, Canada, Colombia, Hong Kong, Mexico, Morocco, New Zealand, Norway, Switzerland, United Kingdom	1
—		Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Kenya, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Nigeria, Philippines, Poland, Portugal, Romania, Rwanda, Saudi Arabia, Singapore, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Türkiye, Ukraine, United Arab Emirates, United Kingdom, United States	1
—		OECD: Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Türkiye, United Kingdom, United States	2
—		Australia, Canada, Germany, Netherlands, New Zealand, United Kingdom, United States	1
—		Australia, United Kingdom	1
—		G7: Canada, France, Germany, Italy, Japan, United Kingdom, United States	4
—		Canada, Japan	2
—		China, Saudi Arabia	1
—		European Union, India	1
—		European Union, South Korea	1
—		European Union, United States	3
—		Germany, Japan	1
—		India, Israel	1
—		India, United Kingdom	1
—		India, United States	1
—		Indonesia, Japan	1
—		Japan, United Kingdom	2
—		Germany, South Korea	1
—		Singapore, South Korea	1
—		South Korea, United States	1

Table 6 (continued)

2020–2021	
Country or Group of Countries	Policy Activity
—	
—	
—	
—	
Total	**70**

2022–2023	
Country or Group of Countries	Policy Activity
Singapore, United Kingdom	1
Singapore, United States	2
Ukraine, United Kingdom	1
United Kingdom, United States	3
Total	**296**

Sources: DPA (2023); author's tabulations using the underlying data.

Notes: "—" indicates that there is no comparable activity entry for the cell during the time period covered by the column. Also note that the DPA Activity Tracker provides information on recent developments in legislatures, judiciaries and the executive branches of the G20, EU member states and Switzerland. Among the AI leader countries most are covered. The DPA tracking does not have separate listings for Ireland or Finland, but they are partly covered via the EU listings. Israel is only covered for its international accords, not for its domestic policy activity.

Table 7: Nature of Recent Machine Learning and AI Policy Developments, January 2020–November 2023 (Counts)

Panel A: Policy Instruments

2020–2021	
Policy Instruments	Policy Activity
Algorithm design and technical standards	23
—	
—	
—	
—	
—	
—	
Content-related regulation and IP, n.e.s.	1
—	
—	
Data protection regulation	9
Direct taxes, including digital service taxes	1
Export licensing requirements	2
Financial grant	5
Instrument unspecified	13
—	
Intellectual property: patents	4
Merger control regulation	1
MNE: Financial incentive	1
Operating condition, n.e.s.	9
—	
—	
—	

2022–2023	
Policy Instruments	Policy Activity
Algorithm design and technical standards	99
Authorization of goods or services	8
Border measure, n.e.s.	1
Business registration requirement	10
Competition authority governance	1
Consumer protection regulation	11
Content moderation regulation	12
Content remuneration regulation	1
Content-related regulation and IP, n.e.s.	4
Cybersecurity regulation	14
Data protection authority governance	7
Data protection regulation	58
—	
Export licensing requirements	5
Financial grant	6
Instrument unspecified	5
Intellectual property: copyright	6
Intellectual property: patents	6
Merger control regulation	1
—	
Operating condition, n.e.s.	4
Operational licence requirement	1
Production subsidy	1
Public procurement access	4

Table 7 (continued)

Panel A: Policy Instruments

2020–2021		2022–2023	
Policy Instruments	Policy Activity	Policy Instruments	Policy Activity
—		Public procurement regulation, n.e.s.	1
—		Quality of service requirements	7
—		Registration and licensing, n.e.s.	1
Service access restrictions	1	Service access restrictions	1
—		State aid, n.e.s.	7
—		Unilateral conduct regulation	3
—		Worker monitoring regulation	9
—		Worker status classification regulation	2
Total	**70**	**Total**	**296**

Panel B: Status of Policy

2020–2021		2022–2023	
Status Types	Policy Activity	Status Types	Policy Activity
Adopted	40	Adopted	114
Concluded	1	Concluded	3
In consultation	1	In consultation	7
In force	11	In force	35
—		In grace period	1
Processing consultation	6	Processing consultation	38
Rejected	1	Rejected	12
Under deliberation	10	Under deliberation	80
—		Under investigation	6
Total	**70**	**Total**	**296**

Sources and *Notes*: See Table 6. In addition, MNE = multinational enterprise; n.e.s. = not elsewhere specified.

Leading AI-Enterprise Host Country Regulatory Specifics

As the global governance framework for AI is still under development, steps taken by the major economies (China, the European Union and the United States; see Appendix 2) may have a significant influence. This influence derives not only from the market power of policy and regulatory actions taken in their own domestic markets, but also from their influence in international bodies (for example, the OECD, the Asia-Pacific Economic Cooperation regional forum (APEC),[42] the G7 and the G20),[43] through their industry associations (for example, the AI Industry Alliance in China or the Partnership on AI and the Data and Trust

42 For information about APEC, see www.apec.org/About-Us/About-APEC/.

43 At the international level, for example, these nations were engaged in the UNESCO "Recommendations on the Ethics of AI in 2021" (UNESCO 2022) and the Bletchley Declaration on AI Safety agreed by most G20 countries and others in 2023 (GOV.UK 2023). Furthermore, in a newly established EU-US tech partnership (the Trade and Technology Council), the European Union and the United States are seeking to develop a mutual understanding on the principles underlining trustworthy and responsible AI (Madiega 2023). They both have endorsed the OECD's Recommendation of the Council on AI, which lays out basic principles (OECD 2019).

Alliance in the United States), and through their trade measures (for example, US export controls affecting third parties). China has been a first mover in AI regulation. Canadian,[44] EU and US regulators also have significant elements in place, often drawing on pre-existing law and regulations applicable to the digital economy more generally (Aaronson 2024). But, they are also moving forward vigorously with AI-specific measures.

Given the potential for cross-border diffusion of AI technology, it is clear that inclusive international coordination is needed to address concerns (Bremmer and Suleyman 2023). This would apply, for example, with respect to matters ranging from traceability and safety to assignment of IPRs and protections (for example, for algorithms). Some aspects will be sector specific (for example, patient safety and privacy in health care), whereas others will be crosscutting (for example, provisions for regulators' access and oversight of algorithms). At the same time, in acting to address such concerns, the international community may reduce impediments to responsible diffusion of AI technology. Such a result could promote more inclusive economic gains from this technology internationally (DSIT 2023).

China's first-mover status in AI regulation has given the authorities valuable hands-on experience to inform future regulation. It appears a range of motivations are involved: a goal of ensuring adequate controls on information content in line with government policy for political and social stability; a desire for transparency and adequate protections; and an objective of having a policy environment conducive to Chinese leadership in AI technologically and commercially, including with respect to ethical norms and standards (Sheehan 2023). China's three-part regulatory framework (Cyberspace Administration of China [CAC] 2021, 2022, 2023) covers algorithmic recommendations, deep synthesis internet information services (for example, virtual reality, deep learning and generative sequencing algorithms) and generative AI services. The framework provides for registration of LLMs, with the first batch of 12 models reportedly being authorized in August 2023 (Liu et al. 2023).

The EU authorities have sought to balance support for AI sector development with concerns about AI safety and conditions for a competitive market. A substantial landmark piece of legislation, the Artificial Intelligence Act, is in advanced stages of development and entry into force is anticipated by mid-year 2024 (for example, see Bamberg et al. 2024; Dentons 2023; Heikkilä 2023).[45] This legislation includes a tiered AI risk management framework that would ban unacceptable risks (for example, models that employ harmful manipulative subliminal techniques), strictly regulate high-risk AI systems (for example, biometric identification and categorization of natural persons), impose transparency and operational obligations on limited risk AI systems (for example, synthetic output from generative AI systems will need to be labelled as such), and permit free use of low and minimal risk AI systems (for example, spam filters or video games), although potentially subjecting them to a future code of conduct. General purpose AI models (foundation models, LLMs) will entail additional compliance requirements to maintain and provide current technical documentation, system transparency, copyright compliance and information on training data. The AI Act also establishes an EU AI office in the European Commission to supervise and enforce certain aspects of compliance in cooperation with a new EU AI board of member country representatives, a new scientific advisory panel of independent experts and a new network of national competent authorities in each member state. Penalties for firm-level violations of compliance requirements could be substantial, ranging from 1.5 percent to seven percent of annual turnover (subject to certain minimum and maximum thresholds). The AI Act will fit into a system of existing measures governing the digital economy in the European Union including the General Data Protection Regulation, the Cybersecurity Act, the Digital Services Act and the Digital Markets Act, among others.

Likewise in the United States, the government has relied on existing legal authorities to discipline AI stakeholders. As US Federal Trade Commission Chair Lina M. Khan (2023, 1) noted, "There is no AI exemption to the laws on the books." So, a crime such as fraud may remain a crime even if the fraud takes place using a new type of technology. With respect to AI-specific regulation, the United States had initially taken a lenient approach before advancing over the past two years in a stepwise fashion, allowing innovation in the private sector to thrive. It set out basic principles

44 The case of Canada is covered in Appendix 2.

45 See also European Parliament (2024).

for AI governance in October 2022, consulted with stakeholders during the first half of 2023, agreed a voluntary regime with 15 leading firms during summer 2023, then followed with a comprehensive Executive Order drawing on existing legislative authorities in October 2023. This measure imposes notification requirements on developers of dual-use foundation models.[46] It also mandates federal agencies to proceed with responsible and strategic exploitation of AI systems, as well as administrative steps to support AI standards, tools and tests, human capital development, research and international cooperation, among other elements.

Other economies engaged in leading-edge work on AI face the challenge of establishing their own domestic AI governance frameworks and defending national interests, while also striving for meaningful cooperation with relevant international institutions and the three major economies (China, the European Union and the United States). Canada provides a useful example (see Appendix 2). Domestically, it is working to complete legislation providing a basis for a principled, risk-based framework for regulation of AI. The Artificial Intelligence and Data Act (AIDA)[47] would provide for further development of AI governance in the nation, while allowing flexibility to maintain coherence with key partner economies internationally, as feasible. Internationally, Canada is relatively well positioned with respect to some relevant digital economy matters covered via provisions of its free trade agreements with the European Union (the Comprehensive Economic and Trade Agreement, and related accords including the General Data Protection Regulation [GDPR] adequacy), with the United States and Mexico (CUSMA) and 10 Pacific Basin partners (CPTPP). For example, these accords can be supportive of AI development with respect to access to data. Canada is also supporting collaboration related to the digital economy (including AI) with members of the APEC forum, the WTO and the OECD, and other international institutions.

Conclusions

AI Innovation Fuels Pressure on Regulators

Over the past decade, the pace of technological advance in the AI sector has accelerated with respect to software architecture and algorithms, training data assembly and mobilization of powerful computing hardware, among other areas. The emergence of readily accessible generative AI has opened the door to broad use of the technology by the wider public. LLMs, in particular, have marked some substantial and highly visible progress. Over the past two years, the release of text-driven LLMs such as ChatGPT and Bard surprised some observers with the levels of functionality provided. While such AI advances are real enough, there is also an element of euphoria among some users, perhaps already anticipating the next steps in AI development (Murgia and Thornhill 2023).

Indeed, despite AI having its early roots dating back to the 1950s, and despite the recent wave of progress in AI development, it is still early days in the AI revolution.[48] Integration of AI into many business processes is only now scaling up. For example, increased application of AI in industrial automation and multitasking robotics has the potential to unlock significant additional productivity gains. There remain substantial unfulfilled AI objectives on the horizon. For example, the long-time AI community goal of delivering artificial general intelligence — that is, the human-equivalent capacity for perception, reasoning, inference and action in an AI system — remains to be achieved. With all that has been accomplished in the sector and the prospect of more powerful systems under development, regulators are indeed feeling some urgency in the need for improved AI governance.

46 The term "dual-use foundation model" means an AI model that is trained on broad data; generally uses self-supervision; contains at least tens of billions of parameters; is applicable across a wide range of contexts; and that exhibits, or could be easily modified to exhibit, high levels of performance at tasks that pose a serious risk to security, national economic security, national public health or safety, or any combination of those matters (Biden 2023). Elliot Jones (2023) provides further elaboration on this type of model.

47 The House of Commons concluded its second reading of AIDA on April 24, 2023. As of January 31, 2024, it is currently under consideration before the Standing Committee on Industry and Technology. See LEGISinfo, "C-27, 44th Parliament," available at www.parl.ca/legisinfo/en/bill/44-1/C-27.

48 For example, although use of embedded AI is widespread in US businesses, the US Census Bureau recently found that as of end of October 2023 only 3.8 percent of US businesses reported using AI to actually produce goods and services, though there is wide variation across sectors (Breaux and Dinlersoz 2023).

Concentration and Diffusion of AI Innovation

At the outset of this paper, a central concern was highlighted to examine the concentration of AI innovation and to consider factors in the regulatory environment that may support or hinder its responsible diffusion. The illustrative assessment of leading AI-intensive firms (see the section "Leading AI-Intensive Firms: A Few Stylized Facts" above) confirmed the extent of concentration for at least two significant populations of AI-intensive firms: those AI-intensive firms in the upper echelon of global businesses for R&D expenditure (selected from among the top 2,500 firms globally for R&D expenditure in all fields); and those AI-intensive firms with success as a start-up in growing their valuation beyond US$1 billion (unicorns). In both cases, the assessment found a fairly high concentration geographically in AI innovators.

The firms in these two populations represent just 11 nations, three of which are members of the European Union. The United States is home to a majority of the AI firms in these samples. The concentration of firms in just 11 host countries may in part be the result of agglomeration effects, whereby development in crowded technology centres may offer some advantages for advancement of AI development and diffusion. For example, thick labour markets may develop and offer large pools of sector-relevant talent. And, improved communication around innovation could emerge due to the proximity of stakeholders, thereby conferring further information advantages.[49]

Internationally, the availability of AI innovation depends in part on openness in channels for technology transfer. This may take place via such means as the sale or licensing of products and services, foreign direct investment, joint ventures and external staff training initiatives, among other possibilities.[50] There are also opportunities for remote access to AI innovation through online hubs and software-as-a-service providers. From the literature review (see the section "Literature: Rapid Technological Development, Unsettled Scholarship" above), some factors associated with diffusion of technology can be identified. For example, availability of adequate protection of IP protection may play a role in facilitating transfers (for example, enabling identification of rights and obligations with respect to transferred intellectual assets). Establishment of an appropriate, aligned international regulatory regime may also help firms to manage risks arising from technology transfer by clarifying responsibilities with respect to safety, consumer protection, security, and promote reliability and trustworthiness in AI, among other issues. Indeed, regulatory misalignment entails costs that may inhibit technology transfer (see Box 2). In the absence of tighter international coordination, there is a risk that inconsistencies may emerge in the regulatory regime internationally and potentially even domestically (for example, between jurisdictions or ministries).

To date, much of the AI regulatory activity has been at the national level as highlighted in the regulatory review section above. The review points to actions under way in a variety of areas potentially relevant to diffusion of AI innovation. For example, already as of 2021, seven of the reviewed economies — five sample economies (Canada, China, the European Union, Ireland and the United States) plus two non-sample countries (Brazil and Singapore) — had policy initiatives concerning standards and certification for technology development and adoption. While international cooperation has supported some peer learning and some convergence (for example, among OECD members), some divergences have appeared. For example, content moderation approaches in the United States or the European Union are inconsistent with the controls on content in China with respect to political and social stability. Among the first 12 LLMs registered under Chinese regulatory requirements in 2023, all originated with Chinese firms and institutions. On the other hand, certain of the non-sample countries considered in the review such as Indonesia, South Africa or Vietnam appear to be lagging in their AI regulatory development in terms of the number of actions under way. Such gaps in regulatory regimes could increase uncertainty around the future conditions for AI businesses and potentially have an inhibiting effect on technology transfer.

The national provisions have been complemented in some cases by AI-relevant international accords that may help to ensure some convergence in regimes. For example, this can be the case in digital economy provisions in some trade agreements.

49 For example, see the discussion on agglomeration in Paul Krugman (1995).

50 For example, Park and Lippoldt (2014) provide an examination of these technology transfer issues from an IP perspective.

Box 2: Regulatory Misalignment Can Be Costly

The OECD (2021, 22) presents a taxonomy of trade costs for producers and traders operating internationally in cases of regulatory divergence. These include information costs related to obtaining and processing information on regulatory requirements (whereby more opaque and complex systems entail higher costs); specification costs to adjust products and services to different requirements (with potential reductions in economies of scale, higher labour and other input costs); conformity assessment costs (demonstrating compliance with different requirements may require additional costly tests, certification, inspections, audits); and other costs, including to the governments administrating the regime.

The burdens of misalignment do not fall equally. Businesses in small economies could be at a particular disadvantage with respect to accessing models, software applications and quality data. Small businesses in those economies could be disproportionately affected, as they often lack capacity to track details of regulatory developments in foreign markets. In addition to misalignment, in some economies, the turbulence of changing regulation may create uncertainty that undermines incentives to invest. For larger economies such as China, the European Union and the United States, there may be sufficient scale in the domestic market to continue to fuel AI development even in a fragmented global AI economy.

These can affect matters such as limiting recourse to data localization, prohibiting imposition of customs duties on data transmission and digital products, ensuring free cross-border transfer of personal data, requiring protection for consumers' personal data and requiring cybersecurity measures (for instance, this is the case with the CPTPP and CUSMA) (Suominen 2021). The EU AI Act goes further to standardize the handling of AI risks across the EU membership, establishing a regional AI regulatory regime and regional AI institutions to guide and oversee the implementation of the legislation in cooperation with national authorities. However, regional trade accords and AI governance regimes do not preclude inter-regional misalignment. For example, the EU AI Act builds in extraterritoriality in that it applies for foreign suppliers to the EU market. But, this does not preclude the possible emergence of regulatory inconsistency with other regimes that those same suppliers may face. At the same time, even less binding commitments such as joint communiqués issued by the G20 or G7 may promote certain types of aligned AI policy action among members and via taskings for other international bodies. Follow-up may take place through reporting processes, soft power means such as subsequent peer review and other methods (for example, even moral suasion among participating leaders).

Success in improving regulatory cooperation (see Box 3) can yield tangible economic results. The OECD (2021, 19) reviewed evidence on the performance of international regulatory cooperation in various fields and found that such efforts delivered improvements in three areas in particular: regulatory effectiveness (especially for challenges that traverse international boundaries); economic efficiency (for example, limiting undue trade friction); and administrative efficiency (for example, domestic regulators may benefit from international intelligence and insights). In light of this past experience including aspects of the digital economy, it may well be that improved cooperation in the area of AI would yield similar types of results.

What Is to Be Done?

Recommendations

In view of the pace of technological change in the AI sector, this paper has examined the concentration of AI innovation and considered factors in the regulatory environment that may support or hinder its responsible diffusion. Drawing on the combined findings from the three analytical sections, the paper recommends:

→ **Designation of an international institution to lead on AI regulatory cooperation:** Replacing the existing fragmented approach, national governments — perhaps via a joint decision of the G20 — may wish to establish a designated AI body at the global level to monitor regulatory

Box 3: What Does Regulatory Cooperation Entail?

Enhanced international regulatory cooperation on AI matters may be key to improved regulatory effectiveness and alignment. The International Federation of Accountants and Business at OECD (IFAC-BIAC) (2018, 5) defines regulatory cooperation as entailing "a variety of approaches, such as negotiated agreements, regulatory partnerships, supranational institutions, or inter-governmental organizations, regional agreements, mutual recognition agreements, trans-governmental networks, and formal requirements to consider international regulatory cooperation when developing regulations." IFAC-BIAC notes that it has the capacity to foster regulatory coherence while preserving countries' sovereignty and addressing unique cultural and domestic policy priorities. According to IFAC-BIAC (2018), curbing regulatory divergence entails international regulatory cooperation; increased alignment in rules; improved alignment in regulatory definitions; better communication and awareness among regulatory agencies on an international basis (for example, to avoid duplicating the burdens of reporting requirements and processes on businesses and bureaucracies); greater transparency in rule making, monitoring and enforcement processes; and greater overall clarity in rules and regulations.

developments and support coordination on regulatory measures. Such an institution could help to promote alignment, AI safety and best practice in regulations. From the discussion in the literature review section above, it appears that viability for such an institution may depend on its being light, agile and responsive, accepted by the major players and able to carry some global authority at least with respect to convening power. For example, this could be a special body established as an independent entity or affiliated with one of the existing international organizations (for example, the OECD).[51] Alternatively, it could be constituted as a joint initiative of multiple existing institutions.[52] Convergence on relevant aspects of monitoring and regulation might be motivated by the benefits of achieving effective, aligned regulation in areas of mutual concern.

→ **Prioritization of regulatory coherence:** International regulatory cooperation promotes coherence and should be advanced. Coherence should be an objective at all levels including among domestic regulatory bodies. In the AI sector, coherence for AI safety measures is a key area for early action, as well as transparency provisions (for AI systems and regulatory processes) and data management regulations (in particular to ensure protections are effective).

→ **Build-in of transparency into regulatory processes and AI systems:** As referenced in each section in the body of this paper, in light of the complexity and potential capabilities of AI technology, it is important that the principle of transparency be embedded systematically in AI governance and products. With respect to the former, businesses and regulators are more likely to achieve intended results efficiently when regulatory processes are clear and predictable.[53] With respect to the latter, in order to protect rights (and encourage provider regulatory compliance) AI system users need to be made aware when they are interfacing with an AI system and when products and services are AI generated.

→ **Promotion of well-regulated data management:** As referenced in each section in the body of this paper, data is a core element in development and operation of AI systems,

51 As noted in the literature review section above, there are proposals in this regard with respect to AI from Bremmer and Suleyman (2023) and, for the digital economy more broadly, from Fay and Medhora (2021). One further model might be the Financial Action Task Force (FATF), which was established as an independent international body in 1989 but is hosted by the OECD in Paris. The FATF sets standards to fight international money laundering and financing of terrorism and reviews their implementation.

52 For example, in the aftermath of the Great Recession (2007–2009), the G20 nations mandated the OECD, the WTO and the UN Conference on Trade and Development to jointly monitor trade and investment policy measures, producing a semi-annual report. More on this initiative can be found at: www.oecd.org/daf/inv/investment-policy/g20.htm.

53 UNESCO's "Recommendation on the Ethics of AI" (UNESCO 2022) goes further, noting, "The transparency and explainability of AI systems are often essential preconditions to ensure the respect, protection and promotion of human rights, fundamental freedoms and ethical principles."

as well as being a key concern for stakeholders (for example, with respect to privacy, reliability and security). Well-regulated data management is needed to protect subjects' personal data as well as third-party IPRs, and to provide clear information on data provenance and nature, while facilitating responsible data access, where appropriate, for AI system development. In this, care is required to avoid imposing undue burdens on responsible data users lest worthwhile scientific advances in AI systems may be inhibited.

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Appendix 1: Screens Employed in Selection of Top AI Firms among R&D Leaders

Table A.1: Illustrative Listing of Top AI Firms for R&D and the Screens Employed to Identify Them, 2021–2023

Company	Schwab AI 25 List (August 18, 2023; excl. AMZN, COF, NNDM, WIT, SOUN, XMTR)	eWeek List (May 29, 2023; excl. DRKTY, AMZN, COF, GEHC, KORE, LOW, LUCY, MCD)	HSBC List: Generative AI and AI Infrastructure in China (October 17–19, 2023; excl. ByteDance, JD)	Partnership on AI (August 18, 2023; excl. AMZN, Deepmind, Fairly AI)	AI Industry Alliance (AIIA, March 2020)	Number of AI Screens with Each Listing	Country of Registry or HQ
Accenture	ACN	ACN	—	—	—	2	Ireland
Adobe	ADBE	—	—	ADBE	—	2	US
Alibaba Group Holding	—	BABA	BABA	—	BABA	3	China
Alphabet	GOOGL	GOOGL	—	GOOGL	—	3	US
Altair Engineering	—	ALTR	—	—	—	1	US
Alteryx	—	AYX	—	—	—	1	US
Ambarella	AMBA	—	—	—	—	1	US
Apple	—	—	—	AAPL	—	1	US
Baidu	BIDU	BIDU	BIDU	—	BIDU	4	China
Broadcom	—	AVGO	—	—	—	1	US
Butterfly Network	—	BFLY	—	—	—	1	US
C3.ai	AI	AI	—	—	—	2	US
Cambricon Technologies	—	—	SSE 688256	—	SSE 688256	2	China
Cerence	CRNC	—	—	—	—	1	US
Ceva	CEVA	—	—	—	—	1	US
Check Point Software Technologies	—	CHKP	—	—	—	1	Israel
China Telecom	—	—	—	—	CHA	1	China
Coherent	—	COHR	—	—	—	1	US
CrowdStrike Holdings	—	CRWD	—	—	—	1	US
Dell Technologies	—	DELL	—	—	Dell	2	US
Duolingo	—	DUOL	—	—	—	1	US
Fortinet	—	FTNT	—	—	—	1	US
Hewlett Packard Enterprise	—	HPE	—	—	—	1	US
Huawei Investment & Holding	—	—	Not traded	—	Not traded	2	China
IBM	IBM	IBM	—	IBM	IBM	4	US
iFlytek	—	—	—	—	SZ 002230	1	China
Informatica	—	INFA	—	—	—	1	US
Infosys	—	INFY	—	—	—	1	India
Intel	INTC	—	—	INTC	INTC	3	US
Intuit	INTU	—	—	INTU	—	2	US
Medtronic Public Ltd.	—	MDT	—	—	—	1	Ireland
Meta	META	META	—	META	—	3	US
Microsoft	MSFT	MSFT	—	MSFT	MSFT	4	US
NetEase	—	—	—	—	NTES	1	China
NICE	NICE	NICE	—	—	—	2	Israel
Nokia	—	—	—	—	NOK	1	Finland
Nvidia	NVDA	NVDA	—	—	NVDA	3	US

Table A.1 (continued)

Company	Schwab AI 25 List (August 18, 2023; excl. AMZN, COF, NNDM, WIT, SOUN, XMTR)	eWeek List (May 29, 2023; excl. DRKTY, AMZN, COF, GEHC, KORE, LOW, LUCY, MCD)	HSBC List: Generative AI and AI Infrastructure in China (October 17–19, 2023; excl. ByteDance, JD)	Partnership on AI (August 18, 2023; excl. AMZN, Deepmind, Fairly AI)	AI Industry Alliance (AIIA, March 2020)	Number of AI Screens with Each Listing	Country of Registry or HQ
Oracle	—	ORCL	—	—	ORCL	2	US
Palo Alto Networks	—	PANW	—	—	—	1	US
Pegasystems	—	PEGA	—	—	—	1	US
Rockwell Automation	—	ROK	—	—	—	1	US
Salesforce	—	CRM	—	—	—	1	US
Samsung Electronics	—	—	—	SSNLF	—	1	South Korea
SAP	—	SAP	—	—	SAP	2	Germany
Seagate Technology	—	—	—	—	STX	1	Ireland
ServiceNow	—	NOW	—	—	—	1	US
Shutterstock	SSTK	—	—	—	—	1	US
Snowflake	—	SNOW	—	—	—	1	US
Sony	—	—	—	SONY	—	1	Japan
SS&C Technologies	—	SSNC	—	—	—	1	US
Stryker	—	SYK	—	—	—	1	US
Synaptics	SYNA	—	—	—	—	1	US
Synopsys	—	—	—	—	SNPS	1	US
Tencent	—	—	TCEHY	—	TCEHY	2	China
Thomson Reuters	TRI	—	—	—	—	1	Canada
UiPath	PATH	PATH	—	—	—	2	US
Zscaler	—	ZS	—	—	—	1	US

Sources: Grassano et al. (2022) (and underlying data linked in that paper); He (2023); Liu (2023); McGuire (2023); Luong and Arnold (2021) (and underlying data linked in that paper); Partnership on AI, industry members, viewed on August 18, 2023 at https://partnershiponai.org/partners/; "AI Thematic Research" at www.schwab.com/client-home.

Notes: 1. Potential candidate AI innovator companies noted in the screens but not covered by the EU Top 2,500 roster: Amazon (AMZN; US), Capital One Finance (COF; US), DarkTrace (DRKTY; UK), GE HealthCare (GEHC; US), Innovative Eyewear (LUCY; US), JD.com (JD; China), Kore Group Holdings (KORE; US), Lowe's Companies Inc (LOW; US), McDonald's (MCD; US), Nano Dimension LTD (NNDM; Israel), WIPRO (WIT; India), SoundHound AI Inc (SOUN; US), Xometry Inc (XMTR; US). Others outside of scope include ByteDance (privately held; China), Deepmind (acquired by Microsoft in 2014; UK); Fairly AI (privately held; Canada).

2. Ticker symbols are for US markets unless otherwise noted: SSE = Shanghai Stock Exchange; SZ = Shenzhen Stock Exchange.

3. "—" means that the firm is not identified as among the firms associated with the particular screen.

4. "excl." means the firm was cited in the screen pool of AI firms, but not covered in the EU listing of the top 2,500 R&D firms. AIIA has hundreds of smaller, privately held members and they are not identified separately here. Huawei is employee-owned and therefore privately held.

Appendix 2: Observations on AI Regulatory Regimes in Selected Sample Countries

Canada

The Canadian legislature is advancing in its work on a law to provide a risk-based framework for AI regulation (Innovation, Science and Economic Development 2023). AIDA[54] is a relatively concise piece of legislation that allows regulators substantial leeway in the specification of future regulation. It identifies high-impact AI systems by a series of illustrative criteria (for example, scale of use, risks of harm to health and safety, imbalances in social impacts, adequacy of regulation of identified risks in other existing legislation). Such high-impact systems would be targeted for potential regulation to mitigate risks of harm. This regulation would be developed in consultation with stakeholders and would take into account interoperability with international frameworks such as the pending EU AI Act.

The Canadian regulations would be guided by a set of principles, including human oversight and monitoring of high-impact systems; transparency for users of AI systems, and their capabilities, limitations and potential impacts; fairness and equity, with actions on the part of AI developers to mitigate discriminatory outcomes; proactive steps by AI developers to mitigate the risk of harms; accountability; and validity with respect to an AI system objectives and robustness with respect to relevant circumstances. The burden of risk evaluation, monitoring and mitigation under AIDA would fall on AI developers. Depending on the severity of violations, enforcement actions might include administrative monetary penalties, prosecution of regulatory offences or criminal prosecutions (for example, where a person causes intentional serious harm to another). Overall, AIDA as currently drafted would go some way in sketching out a framework for ongoing and adaptive AI governance.

However, as Ciuriak and Artyushina (2023) point out, AIDA falls short in terms of institutional development. It does not create a stand-alone agency that would provide a more integrated and comprehensive systemic approach to AI sector development and governance. In light of AI developments, Ciuriak and Artyushina (ibid., 4) press for early establishment of an agency for AI governance in Canada. This agency would "support the development and implementation of regulations, provide after-market oversight, and represent Canada in international fora." It would have a role in shaping conditions in the domestic market that could have an impact on innovation (for example, with respect to timely implementation of international standards). But a Canadian AI authority, armed with insights drawn from Canada's own AI sector and regulators' experiences, should also be in a position to contribute to shaping the emerging international AI governance framework (for example, potentially in relation to the upcoming six-year joint review of the CUSMA scheduled for July 2026).

China

China moved early to establish a regulatory framework for AI. To some extent, this appears to have been motivated by regulators' desire to ensure adequate controls on information content in line with government policy for political and social stability (Sheehan 2023). However, it also reflects a genuine desire on the part of regulators, academics, policy analysts and other stakeholders to provide transparency and adequate protections in the implementation of AI. This concern is balanced with the goal to create a policy environment supportive for Chinese leadership globally in the field of AI, including technologically and commercially as well as with respect to regulation including the definition of ethical norms and standards (Roberts et al. 2021). Indeed, the current five-year plan (2021–2025) features AI as a key area of focus through its "Initiative to Build a Digital China" (Fujian 2021, Part V). China's early mover status on AI regulation has provided a framework that already influences the evolution of AI in the nation. This has conferred some advantages on Chinese regulators, who are gaining experience and know-

54 The House of Commons concluded its second reading of AIDA on April 24, 2023. As of January 31, 2024, it is currently under consideration before the Standing Committee on Industry and Technology. See LEGISinfo, "C-27, 44th Parliament," at www.parl.ca/legisinfo/en/bill/44-1/C-27.

how in this field of technology, which will in turn provide insights for use in future refinements.

The AI regulatory framework includes three main elements so far (Sheehan 2023). At the end of 2021 came the "Provisions on the Management of Algorithmic Recommendations in Internet Information Services" (CAC 2021).[55] This first regulation mandates that such algorithms obey the law and respect professional ethics, fairness, good faith, opennes, and transparency, among other elements. Mechanisms for scrutiny of such elements shall be made available and the models checked periodically. Likewise, information security protections are required including for illegal content or false information, which shall be taken down immediately upon discovery. The regulation includes protections against anti-competitive practices and excessive price discrimination, as well as protections for workers (for example, in the use of algorithmic scheduling). Users gain rights for transparency in the rules for searches and the ability to manage or turn off algorithmic recommendation services.

With an eye toward future regulation, the authorities established an online registry for such algorithms, including their training data and deployment approach. Information from the registry is partially publicly accessible. Moreover, the Standardization Administration of China established the AI Standardization General Working Group to establish standards for LLMs. The group will include domestic industry representatives from leading developers such as Baidu, Alibaba, iFlytek, 360 Security, Huawei and China Mobile. Such arrangements appear to support further public-private cooperation in the AI sector.

The second element of the regulatory framework concerns "Provisions on the Administration of Deep Synthesis Internet Information Services" (CAC 2022).[56] This regulation underscores that deep synthesis internet services shall comply with all relevant laws and regulation, maintain correct "political direction," and respect ethical considerations. The regulation prohibits production, reproduction, publishing and transmittal of fake news information. The regulation emphasizes the responsibility of deep synthesis service providers for the various types of content their systems generate and requires they manage systems in line with the terms of the regulation. Material that may be misleading or misattributed shall be labelled clearly as being deep synthesis generated. Monitoring mechanisms shall be put in place by the service providers and inappropriate content taken down upon discovery and reported to the authorities in a traceable manner. The real identity of the users of these services shall be verified by providers. Internet service providers are required to ensure the security of training data and protection of personal data.

The third element of the framework concerns the "Interim Measures for the Management of Generative Artificial Intelligence Services," which came into effect on August 15, 2023 (Ferguson and He 2023).[57] The state strategy supports domestic innovation with broad application of the technology, as well as international cooperation in foundational technologies such as AI algorithms and frameworks (CAC 2023, Article 3). The regulation builds upon the deep synthesis regulation (CAC 2022), but broadens coverage to include offline AI services. It further elaborates the requirements for text generation in light of increased capabilities of LLMs. Providers are to guide users "to scientifically understand and rationally use content generated by generative AI," avoiding harm to others' rights and interests, and refraining from commercial hype or improper marketing. The regulation underscores the responsibilities of providers to respond to user generation of illegal, malicious or improper content including potential sanctions such as suspension or termination of service provision. Generative AI is to be subject to anti-discrimination requirements with respect to matters such as race, ethnicity, religious belief, nationality, region, sex, age or profession. Content generated is to be "true and accurate, and measures are to be adopted to prevent the generation of false information." Training data is to reflect "veracity, accuracy, objectivity, and diversity," exclude content that infringes IPRs, and respect state cybersecurity and AI content and services requirements. Personal data is to be used either with the consent of the subjects or in line with other legal provisions for such use. The regulation provides for enforcement under relevant law or existing regulations, and where there are gaps this regulation

55 The regulation entered into force on March 1, 2022.

56 The regulation notes that "Deep synthesis technology refers to the use of technologies such as deep learning and virtual reality, that use generative sequencing algorithms to create text, images, audio, video, virtual scenes, or other information" and it provides a list of examples (CAC 2022). The regulation entered into force on January 10, 2023.

57 A English version of the draft regulation is available in CAC (2023).

itself provides for penalties or in the most serious cases withdrawal of use of generative AI services.

A team from HSBC Global Research recently considered the impact of Chinese regulation on the development of generative AI in China (Liu et al. 2023). The authors note that the registration system for algorithms was operational and that a first batch of 12 LLMs had reportedly been approved by regulators in August 2023. All 12 originated with Chinese developers, including Alibaba's Tongyi Qianwen, Baidu's Ernie Bot and Tencent's Hunyuan. The HSBC analysts note that these firms will have a number of options for profitable commercialization of their AI capabilities, such as AI computing power (capitalizing on large graphics processing unit inventories to supply computing services to clients); AI generated content; and model-as-a-service (making models available or customizing models for customers). While American and other foreign firms have a lead in such commercialization globally, Chinese firms such as Baidu, Alibaba and Tencent (the so-called BAT) are moving to catch-up and will have a regulatory advantage in their domestic market. HSBC estimates that the generative AI market in China could reach a scale of US$10 billion by 2026 (Liu et al. 2023).

The European Union

The EU authorities are positively inclined toward AI innovation and use, subject to compliance with existing regulation and pending updates meant to protect users and ensure a contestable market. The EU rulebook is set for a significant upgrade. On December 8, 2023, the European Commission, Council and Parliament agreed on the terms for a landmark comprehensive law on AI, the EU Artificial Intelligence Act. The legal text is now being finalized and will be submitted to the European Council and Parliament for formal adoption in the coming months (Council of the European Union 2023).

Once adopted, the official text of the EU AI Act will be published. It enters into force 20 days later. The application of the provisions will roll out in phases over the next three years. The prohibition on models posing unacceptable risks will apply six months after the law's entry into force. Firms developing general purpose AI models will need to comply within 12 months. The European Commission will have 18 months to provide practical guidelines for the classification of high-risk AI systems. All AI Act rules will be applicable within 24 months in most cases, although operators of certain special purpose AI systems (for example, critical infrastructure; migration, asylum and border control management) will have an additional year to comply.

The EU AI Act governance framework uses a technology-neutral, risk-based approach targeting a range of use cases (for example, see, Dentons 2023; Hoffmann 2023). The new legislation will complement other AI-relevant elements already in place as part of the European Union's approach to governance in the digital sphere. And, it has an element of extraterritoriality: it will apply to providers serving the EU market, regardless of where they are based.

The EU AI Act defines AI systems broadly, drawing on work from the OECD (Bamberg et al. 2024). As of the time of writing, the proposed text of the EU AI Act defined the scope of the legislation as being AI systems that are machine-based and "designed to operate with varying levels of autonomy and that may exhibit adaptiveness after deployment and that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments."[58] The act further elaborates that it is not meant to cover traditional software programs based on rules designed by natural persons to execute specific operations and lacking the capacity to infer.[59]

The pending AI Act employs a four-tiered risk structure (Madiega 2023; Hoffmann 2023; Dentons 2023; Heikkilä 2023; Bamberg et al. 2024), with special supplemental provisions for general purpose AI models.

- The AI Act would explicitly ban AI practices that pose an unacceptable risk to people's safety, livelihoods and rights. According to the pending legislation, this would include AI systems that deploy:
  - harmful cognitive behavioural manipulation techniques;
  - emotional recognition in the workplace or educational institutions (except for medical and safety reasons);

58 This text draws on language from the marked-up legislative text of the EU AI Act, art. 3(1), which was accessed via Bamberg et al. (2024).

59 This text draws on language from the marked-up legislative text of the EU AI Act, recital 6, and accessed via Bamberg et al. (2024).

- algorithms to exploit specific vulnerable groups, for example, those with physical or mental disability) and thereby cause harm;
- algorithms used by public authorities, or on their behalf, for social-scoring purposes and thereby causing detrimental or unfavourable treatment;
- untargeted scraping of facial images from the internet or closed-circuit television footage to create facial recognition databases;
- real-time, remote biometric identification in publicly accessible spaces for law enforcement (albeit with exceptions for certain grievous and urgent matters such as threat of terrorist attack);
- biometric categorization to infer sensitive data such as sexual orientation or religious beliefs; and
- predictive policing of individuals based solely on profiling or personality traits.

→ The AI Act would tightly regulate high-risk AI systems that could adversely affect safety or fundamental rights. Providers and deployers of such systems will face detailed and comprehensive obligations. Among other requirements, such systems would be subject to governance and technical stipulations covering such areas as transparency, risk management, accountability, data governance, accuracy, robustness and cybersecurity. Such high-risk AI systems will need to be subject to human oversight and control. Data for training and use in these AI systems will need to be high quality, relevant and unbiased. In light of the risks, the European Union will require registration of such AI systems in a special database. High-risk systems will be further categorized into two main groups, Annex II and Annex III systems (the latter will have an extra year to reach compliance, 36 months in total):

- Annex II systems are used as a safety component of a product that is itself risk-prone, covered by EU law and subject of a required conformity assessment.
- Annex III systems serve various specific purposes: non-banned biometrics; critical infrastructure; educational and vocational training including systems related to program access, evaluation and monitoring of testing; human resource management in employment; access and use of essential public and private services; law enforcement; migrations, asylum and border control management; administration of justice and democratic processes.

→ Limited-risk AI systems such as chatbots and generative AI systems would be more lightly regulated but still be subject to a set of transparency obligations. Users will need to be informed of their interactions with such an AI system and the limitations of such systems. AI-generated content would need to be flagged.

→ Low- and minimal-risk AI systems (for example, spam filters or video games) could be developed and used freely in the European Union, subject to other applicable laws. However, the EU AI Act envisages creation of codes of conduct for providers of limited- and low-risk systems to guide them toward voluntary compliance with higher AI standards.

General-purpose AI models (foundation models, LLMs) will be subject to further obligations over their life cycle (Bamberg et al. 2024). These include maintaining current technical documentation of the model (including training and testing process, with evaluation results); transparency on properties of the model for downstream system providers; development of a policy for compliance with copyright law; and a detailed summary of the training data employed in the model's development. In cases of systemic risk, general-purpose AI model developers must implement risk assessment and mitigation measures, as well as incident response and reporting procedures.

In addition, the EU AI Act establishes an institutional framework to support and enforce the operation of the legislation. Each member state must designate at least one national competent authority to supervise the AI Act implementation and track AI market developments. A new European Artificial Intelligence Board, with one national representative per member, will oversee this policy area at the EU level. A new EU AI Office within the European Commission is tasked with oversight of the general purpose AI models regime, supporting national authorities, and certain aspects of enforcement. A scientific panel of independent experts will support the EU institutions in this work.

With respect to enforcement, the legislation specifies substantial penalties that depend on the severity of the infringement. These vary between 1.5 percent and 7.0 percent of annual turnover for a firm, subject to certain minimum and maximum thresholds.

As for other AI-relevant EU legislation that would operate in conjunction with the AI Act, a few illustrative examples are cited below:

- Given the expansive exploitation of data through AI technology, the EU GDPR will be quite relevant. The GDPR empowers data subjects to exert some control over the use of their personal data via consent requirements and requires some privacy protections, particularly in relation to profiling and decision making. As with any EU business, AI providers must adhere to principles such as data minimization, purpose limitation and storage limitation when collecting and processing personal data. On the other hand, the GDPR does include allowances for data use for statistical and scientific research purposes. A European Parliament study found that the GDPR "can be interpreted and applied in such a way that it does not hinder beneficial application of AI to personal data, and that it does not place EU companies at a disadvantage in comparison with non-European competitors" (though a variety of specific issues still require clarification) (Sartor and Lagioia 2020, 79–80). GDPR adequacy determinations provide a degree of international access and portability with respect to EU data for certain firms based in a list of registered partner economies. As of January 15, 2024, 15 economies are covered by these decisions including leading AI host countries such as Canada, Israel, Japan, South Korea, the United Kingdom and the United States.[60]

- The EU Cybersecurity Act established a cybersecurity framework for products and services, operating under the EU Agency for Cybersecurity, aiming to harmonize EU-wide cybersecurity certification for information technology products, services and processes. As with other digital systems, AI systems would be covered.

- The Digital Services Act (2022) imposes tiered obligations for online marketplaces and search engines, as well as protections for minors. Obligations include, among others, transparency in areas such as algorithmic decision making and recommendations, and for very large providers, due diligence with respect to annual assessment of systemic risks and regulatory access to databases, algorithms and premises (Beck and Worm 2023).

- If an AI foundational model platform[61] were to attain sufficient scale, for example, the Digital Market Act (2022) provisions might be invoked with consequences for AI system providers. Requirements could include third-party interoperability, limits on the use of personal data and constraints on prioritizing rankings of own products or services, among other possibilities that aim to restore fairness and contestability in the market (Yasar et al. 2023).

- The Digital Governance Act (2022), which aims to facilitate access to publicly held data while maintaining privacy and confidentiality protections.[62]

- The Unfair Commercial Practices Directive (2005), as updated by subsequent guidance.[63] The directive and guidance govern business-to-consumer transactions and representations made by vendors and other stakeholders (for example, providers of comparison tools). The guidance addresses (with explicit references to AI) such issues as tracking and targeting technologies and algorithmic personalization, among other risks.

The United States

As in other countries, AI in the United States is the subject of an emerging regulatory framework. This is not to say that it has been unregulated. At the federal level, the US government included some measures to define AI or address specific concerns such as AI applications in defence or transportation systems. A defence appropriations

60 See https://commission.europa.eu/law/law-topic/data-protection/international-dimension-data-protection/adequacy-decisions_en.

61 AI foundational models are large-scale and intended to be used as a platform to which developers could add additional functionality.

62 See https://digital-strategy.ec.europa.eu/en/policies/data-governance-act-explained.

63 EC, *Guidance on the interpretation and application of Directive 2005/29/EC of the European Parliament and of the Council concerning unfair business-to-consumer commercial practices in the internal market* (see "Digital sector" at §4.2), [2021] OJ C 256/1; online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021XC1229(05).

act in 2020 legislated the creation of the National Artificial Intelligence Initiative Office in the White House to oversee the US national AI strategy. (A number of US states have also legislated measures pertaining to AI, as noted in DPA [2023]).

Operations in the AI sector have also been subject to prior existing regulatory provisions applicable more generally in the economy. Existing domestic law and regulation continued to apply, even in the AI sector. For example, a recent Congressional Research Service review of copyright protection in the sector found that existing copyright law may prove adequate and that additional experience with court challenges would be required to highlight any specific changes in the legal framework that might be required with respect to generative AI (Zirpoli 2023). As the US Federal Trade Commission Chair Khan (2023) put it in another context, "There is no AI exemption to the laws on the books."

Yet, the US approach to AI regulation has been gradually changing in recent years, starting with hardware. In the competition between China and the United States for AI leadership, the United States has focused on perceived security risks, moving to more tightly limit access to advanced AI-related technology of American origin. By means of an Executive Order dated September 15, 2022 (Biden 2022), President Biden expressly mandated that the Committee on Foreign Investment in the United States in conducting investment reviews should consider supply chain resilience and security with respect to AI and related areas of micro-electronics, among other areas. Then, on October 7, 2022 (Bureau of Industry and Security [BIS] 2022), the United States imposed controls on exports to China of certain advanced computing chips and equipment used to manufacture semiconductors, including certain foreign-produced items from third countries incorporating such advanced US technologies. The public notice (ibid., 1) justified the restrictions on national security and human rights grounds and noted the potential military applications for the covered items, as well as uses related to intelligence and security services. These steps went hand-in-hand with the CHIPS and Science Act passed earlier in 2022 by the US Congress, which delivered tremendous support for the US semiconductor sector (US$52.7 billion for manufacturing incentives, R&D, workforce development and more) and explicitly referenced its support for US leadership in the AI sector as an objective (White House 2022b).

Also in October 2022, the White House released its "Blueprint for an AI Bill of Rights" (White House 2022a). The document set out five foundational principles for use in development of a framework for AI governance. These principles are meant to guide the design, use and deployment of automated systems. They cover protection from unsafe and ineffective systems, protection from algorithmic discrimination, protection from abusive data practices (while ensuring users have agency over data uses), user notice and explanation of AI use and impacts, and the ability to opt out and have access to a human (for example, to remedy problems).

In order to get a better view of developments and concerns with respect to AI technology, members of the US administration held structured discussions with AI stakeholders during the first half of 2023. Drawing on this input and cross-referencing the "Blueprint for an AI Bill of Rights" and other recent administrative actions concerning AI, the White House proceeded to secure voluntary commitments from seven leading AI firms to ensure safety, security and trust in developing AI (White House 2023b). Amazon, Anthropic, Google, Inflection, Meta, Microsoft and OpenAI signed on as of July 21, 2023. In September 2023, eight further firms signed on: Adobe, Cohere, IBM, Nvidia, Palantir, Salesforce, Scale AI and Stability (Mitchell 2023).

The key features of the eight US voluntary commitments (White House 2023b) are:

- internal and independent external security testing of their AI systems before their release;
- sharing information across the industry and with governments, civil society and academia on managing AI risks (for example, best practices for safety);
- investing in cybersecurity and insider threat safeguards to protect proprietary and unreleased model weights;
- facilitating ongoing third-party discovery and reporting of vulnerabilities in their AI systems;
- developing robust technical mechanisms to ensure that users know when content is AI generated, such as a watermarking system;
- publicly reporting their AI systems' capabilities, limitations and areas of appropriate and inappropriate use;

- prioritizing research on the societal risks that AI systems can pose, including on avoiding harmful bias and discrimination, and protecting privacy; and
- agreeing to develop and deploy advanced AI systems to help address society's greatest challenges (for example, cancer prevention and mitigating climate change).

The United States announced a further tightening of export controls on October 17, 2023 (BIS 2023). Restrictions were expanded to cover a greater range of advanced computing semiconductors that could potentially "enable the development and production of technologies such as artificial intelligence (AI) used in military applications." The public notice states (ibid., 2), "These controls were strategically crafted to address, among other concerns, the PRC's [People's Republic of China's] efforts to obtain semiconductor manufacturing equipment essential to producing advanced integrated circuits needed for the next generation of advanced weapon systems, as well as high-end advanced computing semiconductors necessary to enable the development and production of technologies such as artificial intelligence (AI) used in military applications." The restrictions concern the 22 countries to which the United States maintains an arms embargo, including China.

As noted by HSBC analyst Frank He (2023, 1), "The affected product coverage is wider than market expectations, which may cause a material impact on China's AI infrastructure supply chain as we estimate that the chips that are newly added to the control list currently support over 90% of AI training workloads in China." The immediate disruption will be limited as Chinese importers anticipated potential disruption and had built up inventories of requisite chips. Also, it is notable that Chinese domestic suppliers such as Huawei and Hygon have improved their chip offerings and can supply viable substitutes for some chips. While He (ibid.) recognizes that the US export controls will incentivize further development in the domestic sector, he argues, however, that a multi-year technology gap may persist in system-level engineering and sees that as a likely constraint on the AI sector in China. Areas of concern include, for example, chip-to-chip interconnection, software ecosystems and advanced node chip fabrications.

The US government took a substantial step to strengthen its AI governance with the "Executive Order (EO) on Safe, Secure, and Trustworthy Artificial Intelligence" issued by President Biden on October 30, 2023 (Biden 2023; White House 2023c). The aim was to advance a coordinated, federal government-wide approach to position the United States for responsible leadership in AI development while addressing AI risks to safety and security. The framework seeks to capitalize and promote benefits from development of AI, while also taking care to mitigate harms. In view of partisan blockage in the US Congress, the Executive Order exploits authorities available to the president under existing law. Still, this action is relatively expansive considering the constraints.

The Executive Order directs that executive agencies use their current powers to develop standards, tools and tests to ensure that AI systems are safe, secure and trustworthy. The approach is risk based, with special reporting measures included covering developers of powerful foundation models. It takes steps to address risks concerning privacy, workplace and other discrimination, and labour market dislocations. The initiative includes measures to support responsible AI use in health care and education. The Executive Order aims to boost AI-related human capital by supporting AI research, facilitating relevant skilled immigration and expansion of federal staffing of AI professionals. Administrative measures would facilitate ramping up use of AI in federal agencies. Openness would be cultivated via support for small business, international collaboration and deployment of AI in meeting challenges global challenges. The document emphasizes the goal of developing and implementing international standards for AI.

On November 21, 2023, the US Federal Trade Commission (FTC) (2023) took a step moving further beyond the early voluntary approaches to AI governance. Under the FTC Act and other laws, the FTC is concerned with fraud, deception, infringements on privacy, unfair commercial practices and competition issues, including instances involving AI. Consequently, the FTC authorized the use of a compulsory process[64] in investigations related to products and services produced or used in connection with AI. Recipients

64 The term "compulsory process" refers to various types of information or document requests – including but not limited to subpoenas, civil investigative demands, and orders for special reports – where the recipient of the request may be compelled to comply with the request by order of court.

of requests for information or documents may be legally compelled to comply by a court order.

As of November 2023, the US Administration's Office of Management and Budget has published for public consultation a draft memorandum with further concrete steps to promote AI governance, innovation and risk management in agencies of the federal government (Young 2023). With the exception of national security agencies, the memorandum would require each agency to designate a senior-level chief AI officer, develop an AI compliance plan corresponding to the memorandum, inventory the agency's AI systems and risks (emphasizing safety and rights impacts), identify potential responsible uses of AI and remove barriers to delivering those systems. Non-compliant AI systems are to be terminated by August 1, 2024. The memorandum identifies specific issues for consideration with respect to each mandate, with milestones, standards, and relatively tight timelines for completion (measured in days and months for initial actions and then for ongoing requirements, depending on the action, annually or biennially).

OECD Recommendation of the Council on Artificial Intelligence

The OECD principles on AI within the OECD's "Recommendation of the Council on Artificial Intelligence"[65] state that:

- AI should benefit people and the planet by driving inclusive growth, sustainable development and well-being.
- AI systems should be designed in a way that respects the rule of law, human rights, democratic values and diversity, and they should include appropriate safeguards — for example, enabling human intervention where necessary — to ensure a fair and just society.
- There should be transparency and responsible disclosure around AI systems to ensure that people understand when they are engaging with them and can challenge outcomes.
- AI systems must function in a robust, secure and safe way throughout their lifetimes, and potential risks should be continually assessed and managed.
- Organizations and individuals developing, deploying or operating AI systems should be held accountable for their proper functioning in line with the above principles.

The OECD (2019) recommends that governments:

- facilitate public and private investment in R&D to spur innovation in trustworthy AI;
- foster accessible AI ecosystems with digital infrastructure and technologies, and mechanisms to share data and knowledge;
- create a policy environment that will open the way to deployment of trustworthy AI system;
- equip people with the skills for AI and support workers to ensure a fair transition; and
- cooperate across borders and sectors to share information, develop standards and work towards responsible stewardship of AI.

65 See OECD (2019). Also note that as of November 3, 2023, the OECD Legal Instruments online database reports that adherence to the recommendation now covers all 38 OECD member countries, plus eight others: Argentina, Brazil, Egypt, Malta, Peru, Romania, Singapore and Ukraine.

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