Centre for International Governance Innovation

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Policy Brief No. 181 — December 2023

Responsible Innovation in Disruptive Digital and Data Technologies

Paul Samson, Constance de Leusse, Paul Fehlinger and Aaron Shull

Key Points

- The convergence of transformative technology, geopolitics and economic trends creates an imperative for "responsible innovation" to mitigate adverse effects, ensure fair benefits and prioritize solutions to common challenges. Decision makers must proactively shape the innovation cycle — influencing design, deployment, scaling, investment — and regulation through evidence-based policy frameworks.
- Transformation will be shaped by seven impactful "verticals" (artificial intelligence, quantum technologies, neurotechnology, Web3, digital public infrastructure, extended reality and biocomputing). Simultaneously, four key "horizontals" (macroeconomics, geopolitics, climate change and regulation) influence the medium-term impact of these verticals.
- Project Liberty and the Centre for International Governance Innovation will collaborate with interdisciplinary researchers to assess disruptive technologies and identify governance gaps. Work will aim to guide decision makers.

Introduction

Rarely in human history has such large-scale, transformative technological change collided with massive geopolitical and economic trends. How do we ensure that the next iteration of the digital economy serves our societies positively, rather than undermining them? The answer lies in "responsible innovation."

This brief's outlook identifies a set of digital and information technologies and global trends that the authors expect to be transformative over the medium term and will be at the heart of near-term efforts aimed at governance. The disruptive potential of these technologies is so strong that responsible innovation must be a key underlying ethos of their development and application. By "responsible innovation," the authors mean a framework that encompasses the "how" of innovation (how to reduce innovation's potential negative consequences and ensure its benefits are equitably spread) and the "what" (by focusing attention on innovation that prioritizes our greatest shared challenges).

Implementing the principles of responsible innovation is a challenge because of the scale, pace and diffusion of technological development. This is compounded by a complex set of interactions with social, geopolitical and economic forces. To meet this challenge and have the greatest impact for the public interest, decision

About the Authors

Paul Samson is president of CIGI. He has 30 years of experience across a range of policy issues with partners from around the world. He is a former senior government official and also served for many years as co-chair of the principal Group of Twenty working group on the global economy.

Constance de Leusse is the executive director of Project Liberty's Institute. She served in the French prime minister's services and then as vice president of institutional relations and empowerment at the Internet Society. She also played key roles in founding the Internet Technical Advisory Committee to the Organisation for Economic Co-operation and Development and in developing the United Nations Educational, Scientific and Cultural Organization's internet governance strategy.

Paul Fehlinger is the inaugural director of policy, governance innovation and impact at Project Liberty's Institute. He co-founded and led the major global multi-stakeholder policy organization for how laws apply to cross-border data flows and services for one decade. He is an expert in what makes innovation ecosystems highly performant, and how venture capital and entrepreneurial solutions can enable the responsible and regulated uses of new technologies.

Aaron Shull is the managing director and general counsel at CIGI. He is a senior legal executive and is recognized as a leading expert on complex issues at the intersection of public policy, emerging technology, cybersecurity, privacy and data protection.

makers need to look earlier in the innovation cycle. Responsible policy frameworks will impact not just how new technologies are used, but also their design, building, deployment, scaling, investment and regulation. This will require policy makers to be proactive, to be well-informed about technologies and to anticipate trends; hence, the authors' focus on a medium-term outlook.

This effort is a joint creation of Project Liberty and the Centre for International Governance Innovation (CIGI). The authors are working together to examine the technologies they believe will rapidly and profoundly shape how we live. This admittedly non-exhaustive list has one commonality: everything on it presents urgent priorities for responsible innovation. The authors' goal is to support well-informed dialogue and proactive agenda setting in technological development, investment, commercial deployment and governance. To do this, the authors will invite further analysis from leading experts on these technologies in 2024, to provide practical framing and in-depth perspectives that inform and support decision makers and national and international deliberative processes.

Technology Vertical and Horizontal Trends

The authors unpack seven technology "verticals," which are poised to have significant medium-term impact, and four "horizontals," which are the forces and trends that will condition and drive the verticals' impact. The authors then set out critical factors for assessing responsible innovation and make recommendations for action through 2024.

Verticals

The seven digital technology verticals below are at different points on the innovation continuum: artificial intelligence (AI) is reaching broad adoption, quantum computing is getting ready for practical applications and biocomputing is just beginning to emerge. However, they all share the ability to disrupt sectors and economies in the medium term.

AI

AI is already deeply embedded in technologies throughout the economy and society (for example, in data analysis and weather prediction, algorithmic health recommendation systems and industrial robots). Generative AI can produce new text, sounds, images and video by using a statistical prediction model. The need for significant training data, skills, capital and "compute" (graphics processing unit chips, energy, networking and storage) means the most powerful foundation models are funded, and often managed directly, by established firms. There is a race for AI supremacy, with big bets placed by governments and private investors on national champions such as Mistral (France) and Aleph Alpha (Germany), and emerging disparities between rich and developing countries. However, private AI investment is dominated by the United States, at $47.4 billion[1] in 2022, 3.5 times the amount invested in China and 11 times the United Kingdom's investment (Maslej et al. 2023, 189).

Through 2024 and beyond, as established model owners license access for enterprise and government applications, generative AI will likely have profound impacts throughout the economy. Growing awareness of externalized costs and harms (copyright, labour, privacy, environmental, security and safety) will focus attention on current issues as well as emerging global risks. Principles developed by the Organisation for Economic Co-operation and Development (OECD); the United Nations Educational, Scientific and Cultural Organization (UNESCO); and the Group of Seven (G7) have spelled out broad ethics and guidelines. The 2023 EU AI Act (European Parliament 2023) focuses on specific harms and individual protections, while the US Executive Order on Safe, Secure, and Trustworthy Artificial Intelligence (The White House 2023) provides an initial framework. With accelerated wide-scale adoption, pressure will increase for more open models and access to powerful computers, especially outside the currently dominant countries (the United States and China). In the medium term, AI will become central to geopolitical tensions.

Quantum Technologies

Quantum technologies include applications in cryptography, sensing, communications and imaging. There is a significant focus on quantum computing, which uses quantum mechanics to do much more complex calculations at speeds thousands of times greater than classical computing. This technology will also supercharge AI applications. Recent developments mean there could be real-world applications within a few years. The complexity of the technology may, however, mean that dissemination will be slow. McKinsey & Company (2023) estimates that by 2030, only about 5,000 quantum computers will be operational.

Nevertheless, private investment is accelerating, with two-thirds of all funding occurring since 2018, so significant developments are expected over the next five years (World Economic Forum 2022, 13). Quantum computing's ability to break traditional strong encryption means that even a limited rollout by powerful actors will have profound impacts on the privacy and security of individuals and in many countries. Planned public investments are greatest in China, at $15.3 billion, the European Union at $7.2 billion and the United States at $1.9 billion (ibid., 11). In the next five to 10 years, applied quantum computing will boost advanced encryption, biotech and financial applications, as well as logistics optimization. The impacts for individual freedoms and national security will be profound. Policy makers will have to adjust their frameworks.

Brain-Computer Interfaces and Neurotechnology

Brain-computer interfaces include neural implants and direct links between the human brain and an external device that can "record, decode and stimulate neural activity" (*Nature Electronics* 2023). Neurotechnological devices currently include "wearables" and external brain-computer interfaces for robotic limbs. In the pipeline are brain implants with the potential, for instance, to diagnose and treat paralysis, seizure disorders, stroke, and degenerative diseases such as Alzheimer's and Parkinson's (UNESCO 2023). In addition to causing human suffering, these diseases cost trillions of dollars in care-related costs globally (Insel, Collins and Hyman 2015). Neurotechnology will have broad applications in health, AI, robotics and beyond. Ethical issues of testing on animals

1 All dollar figures in US dollars.

and humans are a core concern of responsible innovation. These technologies could also be used to manipulate people and gather information about their thoughts, emotions, memories and identities. The potential threats to human agency and fundamental freedoms are significant, and UNESCO is developing an ethical framework. As technologies emerge and are implemented, issues of equity, access and choice will be prominent. Today, it is questionable whether policy makers have fully grasped the challenges that are on the mid-term horizon in the fields of neurotechnology and brain-computer interfaces.

Web3 and Decentralized Technologies

Web3 is decentralized web infrastructure built with blockchain technology. Blockchain ledgers can enable decentralized data storage and ownership, thereby enabling greater levels of data control, economic value participation and interoperability of web services. This technology is also applicable for alternative financial products ("defi," or decentralized finance). Web3 also allows the development of technical protocols for the social graph that gives users more agency over the personal data they share with intermediaries (for example, in social media). Many of these applications are already operating, but not at scale. Following crypto industry scandals and the shift to AI, investment in Web3 has fallen. However, it is expected that new models based on greater individual control and agency will continue to emerge and grow in the coming years, especially in regions where there is less faith in financial institutions and the rule of law. Broader socio-economic effects will notably include the environmental impacts of energy and water consumption, money laundering, and challenges in the regulation or policing of cybercrime, harassment and the dissemination of illegal content. Defi alternatives to traditional financial infrastructure will continue to attract investment as resources for lesser-served and more innovative communities. Not only will this impact various economic sectors, but it will also trigger new regulatory approaches.

Digital Public Infrastructure

Digital public infrastructure (DPI) consists of public benefit technologies, protocols or capabilities for areas such as digital identity, payments, social networking and data exchange, deployed or supported either by governments or public interest actors. Government-issued DPI is already in use in several countries. Aadhaar, India's biometric digital identity system, reaches more than 1.3 billion people and is a key part of the "India Stack," which is defined as "government-backed APIs, or application programming interfaces, upon which third parties can build software with access to government IDs, payment networks and data" (Parkin and Reed 2023). Partial versions of the India Stack are being deployed in Ethiopia, Morocco, the Philippines and Sri Lanka, and more countries are likely to adopt it or deploy similar capabilities, following its prominence during the 2023 Group of Twenty (G20) Summit in India. As DPI connects digital identity to other activities and services, and deprecates cash in favour of digital transactions, it increases citizens' legibility to governments. In the mid-term, this will entail significant risks for privacy and other freedoms. State-led DPIs will aim to complement and enable private investment; for example, Brazil's "Open Health" program aims to provide access to currently fragmented health records through a universal, standardized and interoperable data infrastructure that increases transparency and competition (Kuzev and Brown 2023). Socially responsible DPI also emerges in other fields, where it is driven by public interest actors. Notable examples include new public interest infrastructures for technical protocol architectures such as the Decentralized Social Networking Protocol (DSNP) for healthier social networking,[2] virtual worlds, and open AI models that seek to build the enabling infrastructure of a more socially responsible, open and competitive digital economy. The growing field of public interest technology is beginning to have global impacts.[3]

Extended Reality

Extended reality (XR) includes virtual, augmented and mixed reality. It combines virtual and physical space and interactions by creating "digital twins" that match what we do in the physical world, often via headsets or wearables. XR ranges from total immersion to smart glasses with an overlay on reality. It is currently applied in gaming and entertainment, training, remote working (for example, in telemedicine), engineering and manufacturing. Its hardware has not been

2 The DSNP is supported by Project Liberty; see https://dsnp.org/.

3 See https://pitcases.org/.

adopted as quickly as expected, and capital-intensive initiatives such as Facebook's/Meta's "metaverse" have not significantly taken off. The high requirements for user connectivity, computing power and equipment mean XR is still not ripe, but growing adoption is expected at a steady pace in the near future. XR, particularly when combined with advances in AI, has the potential to improve access to training, education, health care and work, reducing inequalities within and between countries. However, speed of deployment will depend on capital investment, open standards and protocols, and also how decentralized virtual worlds will be. Public actors around the world, such as the European Commission, will start exploring how to regulate future virtual worlds.

Biocomputing and Synthetic Biology

Biocomputing uses organisms such as living cells as a substrate for computation and storage, just as silicon is used as a substrate in traditional computing. Synthetic biology uses digital technologies to engineer cells and molecules, including DNA. Together, they can design and build tiny computers based on proteins or cells. These are slower than traditional computers but vastly more energy efficient and can store much more information. The DNA in one millilitre of bacteria could store the information of the entire internet (Gent 2023). This technology could also act as tiny robots, treating disease, or as interfaces. Applications at an early stage of development include smart materials and electricity-conducting polymers that grow inside living plants to form circuitry, with potential use in agriculture. Biocomputing could have profoundly transformative applications across food security, energy production and human health, but is still emerging.

Vertical Conclusions: Cross-Cutting Impacts and Global Equity

These seven technology verticals are expected to help shape the next five years, but it is the *interaction between them* that amplifies disruption and transformation. This interaction may also trigger impact synergies; for example, DPIs will collect more personal data, feeding AI systems that may also be leveraged with quantum computing. The World Intellectual Property Organization's *Global Innovation Index 2022* identified two novel innovation waves: digital (supercomputing, AI and automation); and deep science innovation (biotech, nanotech and new materials) (Dutta et al. 2022).

There will be significant disruptions at the intersection of data, AI, robotics and XR, bringing novel approaches, but also raising a range of issues about data ownership and autonomy, and public benefit investment. We may begin to see transformation of entire sectors; for example, health will be transformed by precision and personalized medicine, driven by advances in genetic data, digital drug development, health-data spaces, robotics, telemedicine, and the sharing and analysis of biodata.

Many of these disruptive and transformative technologies risk exacerbating existing global inequalities, both within and between countries. For example, several of the most widely used large language models are directly run by existing US and China-based technology platforms (Kosma 2023). Of the top 10 AI patent owners in the past 10 years, seven are in China, two are in the United States and one is in South Korea.[4] Currently, 50 percent of neurotech companies are in the United States, with another 35 percent in Europe and the United Kingdom (UNESCO 2023). Less developed countries face barriers in access, adoption and diffusion. Responsible innovation includes actively working to ensure benefits and opportunities are widely shared.

Horizontals

Horizontals are the "giga-trends" — the key socio-economic and geopolitical forces and developments shaping how emerging technologies impact us. They include how debt levels and higher interest rates dampen risk appetite and investment capital, and how this can reduce

4 For patent owners in machine learning and AI worldwide from 2013 to 2022, by number of active patent families, see www.statista.com/statistics/1032627/worldwide-machine-learning-and-ai-patent-owners-trend/.

development and access to new technologies. The horizontals also include climate change, regulation, and increasingly volatile and transactional geopolitics. They highlight pressing planetary concerns where responsible innovation could be targeted to meet our greatest global challenges.

Macroeconomic Trends

Higher interest rates and debt levels in most countries that have traditionally driven technological innovation will continue to lower risk tolerance and the availability of capital for investment. Extremely high-investment technologies such as generative AI may continue to be dominated by existing industry incumbents, driving an increasingly public discussion about equity and access. Higher interest rates and public debt also present a constrained environment for public investment in transformative technologies. However, this may also focus attention on due diligence, sustainable revenues, broadly scalable use cases and the need for public-private collaboration to tackle humanity's toughest challenges. Negative and persistent trends relating to economic inequalities continue within most countries. Arresting these trends will be an essential part of policy responses.

Geopolitical Competition

War, conflict and intense geopolitical rivalries, such as the Cold War, can lead to accelerated innovation and transformative technologies first developed for military purposes (for example, the internet and drones). Be it AI or quantum computing, major technology trends in the next five years will be dual-use technologies. Conflict and volatility are driving investment; for example, the North Atlantic Treaty Organization Innovation Fund focuses on AI, autonomy, biotechnology, next-generation communications and space. For the first time, the European Union has outlined an economic security agenda, focusing on the four technologies it wants to keep "safe" for Europe (advanced semiconductors, AI, quantum and biotech) (European Commission 2023). Broader geopolitical and geoeconomic changes will include China's internal consolidation of power and changing demographics; multipolarity; the activities of the BRICS (Brazil, Russia, India, China and South Africa); Africa rising; and the increasing movement of people in response to political turbulence and climate crises. Responses to these developments include "friend-shoring" (i.e., concentrating supply-chain networks in closely allied countries), China's Belt and Road Initiative, and data sovereignty/protectionism rules that limit competition and the free flow of data. However, supply-chain disruption and reinvention may also create opportunities. The impacts of all these factors on technology developments include chip availability; access to powerful compute, energy, water and high-level skills; competition for rare earth materials and other resources; and full strategic competition on quantum and AI.

Climate Crisis

The year 2024 is likely to be marked by continuing extreme weather events and growing public concern about technology platforms' share of more limited and intermittent energy and water resources. Decarbonizing economies making the switch to electrification will see increased demand for energy and pressure on electrical grids, driving dependence on transitional sources before fully renewable sources come online. The growing energy and water demands of AI use will add to demands for a more carbon-neutral digital economy. While the tighter financial climate and geoeconomic competition could be a barrier to investment in less energy-intensive computing, they could also increase market incentives to use fewer resources. Climate and clean tech more broadly will receive significant investment, and the predictive powers of AI will be employed in weather, financial services such as insurance, emissions-trading markets and elsewhere. The more distant but potentially transformative promise of low-energy biocomputing may attract investment.

Technology Regulation

The 2020s have seen digital and data technology become regulated, similar to how financial services were in the 1920s. Around the world, comprehensive frameworks are being adopted at national and international levels. Europe is a trendsetter in the regulation of new technologies, with its major regulatory packages on digital services, data, AI and competition that will likely inspire similar frameworks elsewhere. Africa, with its 2063 framework, and Latin America and the Caribbean, through the UN Economic Commission for Latin America and the Caribbean process, are exploring establishing single digital markets through harmonized regulations to enhance

cross-border data flows and services. Several new international frameworks (on AI in the Council of Europe and neurotechnology at UNESCO) are being discussed. New regulation can make innovation more cumbersome, but it can ensure consumer protection, security, competition and choice, and lower market barriers to encourage future innovation by new entrants. It can also provide essential legal certainty for investors, for example, when the legalization of strong encryption in the late 1990s unleashed commercial web-based services. Regulation of generative AI is likely at the national level, often prompted by international coordination initiatives, but it may be constrained by concern for national competitiveness.

Responsible innovation reduces or mitigates harms and drives more equitable distribution of benefits, but it has a key third plank: focusing collective efforts on fundamental challenges that bring together all stakeholders (international organizations, governments, businesses, investors, civil society, technologists and academia). It requires governance across existing gaps to anticipate future benefits, harms and opportunities to serve wider goals. International governmental organization processes such as the UN Secretary-General's Global Digital Compact initiative, other global governance efforts such as the G7 and G20, the OECD, regional and national processes, and multi-stakeholder processes are critical to ensuring that responsible innovation equitably and effectively tackles global challenges.

Responsible Innovation Could Soften the Impact of Geoeconomic Trends

Looking at how the verticals and horizontals interact, there is a risk that both public and private investors focus almost exclusively on winning technological arms races — either for sector dominance or geopolitical rivalry — and deprioritize ethics and responsible innovation. However, any short-term, narrow gains may come with wider social and economic costs, further driving inequality and tensions. Responsible innovation builds more stable and profitable businesses than unfettered disruptive approaches.

To make this work in a more accelerated and transactional world, innovators and regulators need new ways to discuss innovation challenges as a common concern. Dialogue, transparency and ongoing consultation and learning are essential to ensuring responsible innovation works for everyone. However, there is a risk of the regulatory pendulum swinging back too hard toward overregulating, after the long period of "light-touch" regulation in the early 2000s.

Key Responsible Innovation Factors

Innovation in data and digital technologies can be assessed to determine whether it is responsible by questioning its impacts against the following criteria.

- **Ethical values:** Are the innovation impacts and methods ethical? Do they align with defined sectoral ethical principles and values such as human rights, fairness and justice?
- **Societal well-being:** Does the social impact contribute to social well-being (for example, shared gains in living standards), or does it exacerbate social inequalities and erode democracy?
- **Economic fairness:** Does innovation reduce or increase economic and social inequality? Does it support competition, not gatekeeping, and maintain open pathways for future innovation by new entrants, letting users control their data and participate in the economic value created with it? Are its economic benefits widespread rather than concentrated?
- **Environmental sustainability:** Is the innovation environmentally sustainable, both in its development and scaled implementation? Is it sufficiently carbon-neutral or negative, and does it impact neutrally or positively on ecosystem health and biodiversity?
- **Inclusivity and accessibility:** Is the innovation broadly inclusive and accessible? Does it exclude certain populations or maintain existing inequalities? Has it been developed

and is it governed with real engagement and input from the people it will affect?

- **Privacy, data agency, human dignity and security:** Is the fundamental right of individual privacy and agency over personal data designed as part of the innovation? Does it increase people's digital autonomy and choice, or are there dark patterns in the design? Does it impact security, including cybersecurity?

Assessing innovations using these factors will help to ensure that transformative digital technologies are a net positive to humanity and help to tackle our greatest challenges. More broadly, it will be essential to ensure there are targeted channels and opportunities for technology transfer and access. Innovators in countries outside the current narrow list of countries that dominate investment in most of the seven key technologies need more opportunities to be part of the coming wave of disruption and transformation.

Recommendations for an Effective, Responsible Innovation Agenda

Below are five high-level recommendations for policy and industry leaders working in a multi-stakeholder fashion in 2024, with a view to the next five years. They are aimed at anticipating risks, managing opportunities, and leveraging digital and data innovation for the greatest good.

- Develop a common approach to assess innovation and ensure it is ethical by design. Set global, quantifiable metrics for measuring the impacts of technology through scientific evidence inspired by the Intergovernmental Panel on Climate Change.
- Identify mechanisms to counterbalance negative market externalities of new digital technologies (AI, social media, virtual worlds and so forth) through public interest technologies and other frameworks such as open-source technology or economic redistribution mechanisms to enhance positive societal benefits, innovation and competition in developed and developing countries.
- Develop a clear set of criteria for ethical investment in tech for public and private sector investors.
- Invite businesses to develop mainstream standards for a new corporate function (i.e., establishing chief digital ethics or responsible innovation officers) at the executive level. Create ethical deployment units in all large-scale tech companies.
- Invite governments to structure consultation channels for researchers, civil society, the private sector and citizens to understand and influence the impacts of technological innovation, and to strengthen stakeholder consultation mechanisms in their existing processes.

Next Steps

Effective and responsible innovation requires urgent mainstream attention and evidence baselines, similar to what we have seen with climate action in the 1990s: strategic direction, effective and appropriate governance, sufficient investment, resources, timelines, broad collaboration and knowledge sharing. This is why Project Liberty and CIGI will work together in the coming months, partner with other interdisciplinary researchers to sharpen our assessment of emerging disruptive technologies, and reach a deeper understanding of upcoming risks, opportunities and responsible innovation challenges and priorities. What, if any, governance gaps exist, and how can we ensure responsible innovation all the way through the transformative technology pipeline? The authors' forthcoming work will support decision makers in understanding the key questions they need to ask at each of the different innovation stages of transformative digital and data technology.

Acronyms and Abbreviations

AI	artificial intelligence
CIGI	Centre for International Governance Innovation
defi	decentralized finance
DPI	digital public infrastructure
DSNP	Decentralized Social Networking Protocol
G7	Group of Seven
G20	Group of Twenty
OECD	Organisation for Economic Co-operation and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
XR	extended reality

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About CIGI

The Centre for International Governance Innovation (CIGI) is an independent, non-partisan think tank whose peer-reviewed research and trusted analysis influence policy makers to innovate. Our global network of multidisciplinary researchers and strategic partnerships provide policy solutions for the digital era with one goal: to improve people's lives everywhere. Headquartered in Waterloo, Canada, CIGI has received support from the Government of Canada, the Government of Ontario and founder Jim Balsillie.

About Project Liberty's Institute

Project Liberty's Institute is an independent, non-partisan organization founded in 2021 with three academic partners: Stanford University, Sciences Po and Georgetown University. Its mission is to enhance ethical governance by supporting timely, actionable research on digital technology and responsible innovation. The Institute serves as an international meeting ground for technologists, policy makers, academia, civil society, entrepreneurs and governance experts. Together, these interdisciplinary partners and leaders from the public and private sectors create frameworks for how we design, invest in, deploy and govern new technologies.

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67 Erb Street West
Waterloo, ON, Canada N2L 6C2
www.cigionline.org

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