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COMMITTED TO IMPROVING THE STATE OF THE WORLD

White Paper

Global Technology Governance

A Multistakeholder Approach

In collaboration with Thunderbird School of Global Management and Arizona State University

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World Economic Forum
91-93 route de la Capite
CH-1223 Cologny/Geneva
Switzerland
Tel.: +41 (0)22 869 1212
Fax: +41 (0)22 786 2744
Email: contact@weforum.org
www.weforum.org

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Executive summary

The dynamics of the Fourth Industrial Revolution mean that systems of governance are, on the whole, failing to deliver what is needed in terms of minimizing risks and costs, while maximizing opportunities and benefits. This is true at all levels – global, regional, national, subnational and local – and across the public sector, among businesses, in the media and within civil society.

Governments and private-sector governance bodies – such as standards bodies – are familiar with the pressure to deliver beneficial governance, and many are responding. However, they are running up against a range of challenges that include barriers to cooperation, gaps in the governance landscape, divergent interests and conflicting incentives.

As a result, governance approaches around the world that are linked to emerging technologies vary widely in terms of degree of institutional development and diversity of process. Nevertheless, today there is a lack of coherence and integration among approaches in two senses:

– Vertically: among different layers of government, corporate or organizational control
– Horizontally: across different countries, disciplines, departments and technological domains

True global governance – understood as the norms, principles, decision-making processes and institutional arrangements that set standards and create incentives for behaviours at a transnational level – is even less developed and is, at best, a patchwork of approaches.

Varieties of policy can stem from cultural differences or simply reflect a diversified strategy of approach. Neither of these is necessarily problematic. Nonetheless, there are some important global governance cross-cutting issues and themes such as interoperability, privacy, access and inclusion, employment and sustainability where common interests and existing mechanisms can be drawn on to create global norms.

There is also promising movement at the technology level, as coalitions of actors form at the national, supranational and global levels to accelerate the safe and inclusive development of emerging technologies such as artificial intelligence (AI), precision medicine, drones, the internet of things (IoT), autonomous vehicles (AVs) and distributed ledger systems.

However, there are far too few legitimate, rigorous and truly multistakeholder processes that support the sharing of ideas, innovations and lessons for governance in *diagonal* ways – i.e. promoting both vertical and horizontal coherence simultaneously.

To move forward, stakeholders urgently need to:

1. Share and co-create inclusive and participatory approaches to technology governance
2. Adopt agile, digital mindsets
3. Invest in digital skills and digital leadership inside the public sector
4. Create a climate for technology policy experimentation
5. Open public policy-making processes to new stakeholders
6. Think – and collaborate – across borders and in the international sphere
7. Promote human rights and ethics-based approaches as the basis for defining responsible use of digital and emerging technologies
8. Create models for the translation of policy across sectors and disciplines

Introduction

As the World Economic Forum has noted previously in its work on agile governance,[1] the innovations at the heart of the Fourth Industrial Revolution are affecting economics, politics and society at rates, scales and depths that demand governance approaches with greater agility and broader perspectives when compared to existing approaches.

Successfully developing and implementing agile approaches to the governance of emerging technologies is far easier said than done. The speed with which new technologies converge, resulting in new applications and new technological combinations, increases the rate of obstacles and dilemmas for institutions and societies. At all levels – global, national, municipal, organizational and even familial – we are struggling to develop and enforce new sets of rules and behaviours at an equivalent speed in order to get the most out of emerging technologies while managing their risks.

Understandably, existing regulatory bodies tend to be both specialized and confined to national or subnational jurisdictions. Where rules do exist, they tend to affect the use of technologies in relatively narrow contexts. Nevertheless, emerging technologies are combining and diffusing in ways that are simultaneously transforming trade, finance, labour markets and value chains across a wide number of industries and geographies, thus blurring traditional regulatory boundaries.

At this stage of the Fourth Industrial Revolution, therefore, there is no central point of reference for technology governance, and relatively few "leading practices". There is also a significant gap in terms of *global* governance – namely, rules, policies and practices that enable benefits and risks to be managed across sovereign borders.

This white paper looks to take a small but meaningful step towards filling that gap. It is a deeper exploration of the landscape of global technology governance. Its goal is to highlight the common priorities, barriers and roles of stakeholders in unlocking the benefits of emerging technologies while managing their negative impacts.

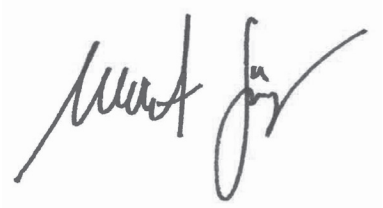
By doing this, the white paper expands upon the call for "an operating system upgrade" for our current governance processes expressed in the World Economic Forum's publication on Globalization 4.0.[2]

As a resource for a multistakeholder audience of engaged decision-makers, this contemporary snapshot of governance priorities, challenges and emerging policies provides a condensed view of where technology governance stands in 2019, drawing on the World Economic Forum's Global Fourth Industrial Revolution Councils. These councils bring together more than 200 leaders from the public and private sectors, civil society and academia from around the world.[3]

- **Part 1** of this white paper defines what we mean by governance, presents a range of frameworks for assessing technology governance and discusses the dynamics of emerging technology governance in the Fourth Industrial Revolution.
- **Part 2** of this white paper provides an overview of the landscape of tech governance in 2019 and highlights a range of cross-cutting issues critical to international policy-making.
- **Part 3** details a range of barriers and gaps inhibiting collaborative governance and sheds light on important interests, incentives and conflicts that must be addressed and resolved.
- **Part 4** provides a framework for engaging and working together and examines what stakeholders can do to bring attention to these areas as well as drive collaboration from their positions of interest.

The World Economic Forum is the International Organization for Public-Private Cooperation, and this white paper is part of the platform of support for collaboration on technology governance. Governments, businesses, academics, technical experts and societal leaders can benefit from the rich contribution of the hundreds of experts who have given their time and input to this document, especially as they aspire to surmount the governance challenges of emerging technologies and reap the benefits they bring. In complement to this white paper, the World Economic Forum will continue to support cooperation and provide space for reflection and dialogue to discuss the modernization of our international architecture at a new Global Technology Governance Summit in 2020.

This initiative will enable a broad cross-section of stakeholders to cooperate on technology governance at the global level and continue to fulfil the mission of the World Economic Forum to improve the state of the world.



Murat Sönmez
Managing Director
World Economic Forum

Part 1: What is governance and why is it necessary?

The Fourth Industrial Revolution is straining political, economic and social systems around the world. The norms, rules, guidelines and governance processes that we have relied on to ensure technologies, companies and individuals behave in accordance with our values and expectations are proving sorely lacking. For example, in some areas, such as the challenge of ensuring that machine learning systems treat all people fairly, the principles seem clear while the governance mechanisms are not. Who do people call to make a complaint? Who is responsible for machine learning outcomes? How do we distribute accountability in such systems?

Other technological concerns demand more than just creating policy. For example, when integrating unmanned, autonomous aerial systems into a crowded civilian airspace currently dominated by human-piloted aircraft, the issue is less about a lack of policy than it is about ensuring their effectiveness by updating those that already exist. There is the added complication that, as drone technology evolves, the need for updating may become perpetual in order to maintain relevance.

In almost every area of life, emerging technologies are advancing, integrating into new business models, creating new, transformative products and services, and altering the way the world works far faster than our laws, regulations and standards can react. Leaders are looking for rules and guidance, while industries highlight their self-regulatory capabilities and public-private partnerships develop co-regulatory strategies. In fields as diverse as transport, media, telecommunications, manufacturing, energy, staffing, medicine, engineering and construction, in all sectors and almost all geographies, new or better rules are required.

The desire for greater productivity and higher levels of prosperity for citizens around the world is a clear motivation in the continued landscape of innovation. Emerging technologies offer significant opportunities for sustainable wealth creation, but a great deal of governance relates to values complementary to, but distinct from, economic goals.

Fundamental, shared values – such as the common good, respect for human dignity and stewardship of the environment[4] – are being challenged by emerging technologies as they change the way that economies, politics, ecologies and societies operate. Other deeply held values, which are prioritized differently across nations, are at stake as new technologies proliferate. Notable among these are expectations of privacy and security,[5] the legitimacy and independence of democratic processes,[6] sovereignty and notions of fairness and justice before the law.[7]

Governance challenges such as these demonstrate that the rules and systems designed for prior industrial revolutions must be adapted to new stresses and new opportunities in order to responsibly raise the quality of life for populations around the world.

Governments recognize the demand for governance that new technologies create. For example, in recent years, as with nanotechnology and biotechnology, some governments have moved to create new governance regimes around other technologies such as self-driving vehicles.[8] Others have launched strategies around the development and deployment of AI,[9] while still more have created innovative spaces to explore the benefits and challenges of blockchain,[10] to name just a few areas of experimentation.

Governments, however, are not the only actors responsible for policy development when it comes to sophisticated technologies. Expertise is a scarce resource and some of the most powerful technological systems and largest datasets are managed by private companies. Corporate policies and norms – in the form of interactions with policy-makers, product development processes, user agreements, decision-making protocols, privacy policies, training systems and employment strategies – are also essential and powerful governance engines.

This section provides a range of frameworks through which to assess and understand governance, setting the scene for the landscape described in Part 2.

1.1 Definitions

Defining governance

By governance, we refer to making decisions and exercising authority in order to guide the behaviour of individuals and organizations.[11]

Governance can be achieved through the creation and enforcement of explicit rules or incentives (backed by the power to reward or impose sanctions), but also through the development of social norms, guidelines, standards, policies, ethical principles or command structures. Governance tools have been increasingly used in recent years because they are more pliable than hard law and thus can offer the advantage of greater agility even if enforcement may be more difficult.

While governance has been primarily seen as the remit of the public sector, governance goes beyond the boundaries of governments.[12] In fact, it is an activity that occurs daily across privately held organizations, within formal and informal civil-society organizations and even in social contexts among family and friends. As a result, the term "governance", as it is used in this document, refers both to traditional forms of policy-making and to the increased engagement of non-government actors in non-hierarchical policy-making processes.[13]

Defining technology governance

Technology governance, by extension, involves making decisions and exercising authority on the development and diffusion of technology. The direct purpose of technology governance is to guide the behaviour of individuals and organizations towards a specific set of outcomes.

For this reason, technology governance often involves the creation of incentive programmes, laws, regulations and supervisory bodies by public authorities. Additionally, it includes the development and enforcement of corporate policies, ranging from investment choices to collaboration strategies to guidelines on the ethical use of technology.

The national and international standards bodies and associated standard-setting processes are a critically important set of private actors in technology governance. Together, these guide the behaviour of large numbers of companies and users by setting technical standards that influence technological investment, design and use. These standards are often adopted by governments in legislation and make their way to the international stage through agreements.

Technology governance is related to and overlaps with technology policy, but the two are not entirely synonymous. Policies can be a part of governance, but governance can extend beyond explicit legal or formal corporate rules or procedures. It can be indirect, informal and implied. It can drive expected behaviours through practice and culture. Indeed, these informal expectations are often considered policies in their own right. A semantic discussion is not necessary to recognize the broad range of governance potential beyond formal regulatory procedure.

Technology policies can be developed to solve major concerns such as market failures linked to underinvestment in innovative products, services and processes.[14] Technology policy is therefore an important tool to "promote the production, diffusion and use of scientific and technical knowledge in order to realize national objectives".[15] Technology policy and other governance measures can also be developed in order to influence behaviours around investment and the use of emerging technologies.

Other forms of technology governance – such as the regulation of medical devices or the environmental restrictions on vehicles – focus on potential market failures linked to the risks or negative externalities of technologies. In the public sector, technology policy is often seen as the domain of those departments charged with supporting innovation, industry and science, while the broader issue of technology governance is more widely distributed across government, influenced by regulations overseen by environmental, transport, justice and resource-related departments.

The critical point here is not to draw unnecessary lines, placing these concepts in separate categories. Progress in either or both requires the collaboration of multiple stakeholders who relate to the challenges of emerging technologies in different ways and with different levels of power and influence.

Defining global governance

By *global* governance, we refer to the creation or emergence of factors that effectively and consistently guide the behaviour of individuals and organizations across national boundaries. Currently, there is a deficit in global governance of technologies due to the lack of coordination in policy creation that represents shared strategies even without shared authority.

In this definition, global governance does not require or imply a super-sovereign, international authority with the power to make or enforce rules over the wishes of individual nations. Rather, technological governance can be global if, in its impact, it materially and significantly affects the development, behaviour or use of technologies across multiple countries simultaneously.

This definition of global governance is able to encompass many examples of globally relevant rule-making in technology governance, including:

1. The International Organization for Standardization (ISO), the world's largest developer of voluntary international standards
2. The World Intellectual Property Organization, the global forum for intellectual property (IP) services, policy, information and cooperation

3. The World Trade Organization, which oversees the global framework for negotiating trade agreements as well as an accompanying dispute resolution process
4. California's Air Resources Board, which defined vehicle emissions standards in a critically important market for car manufacturers
5. Facebook's Data Policy, which governs how the company manages the data of almost 2.4 billion monthly active users

As Grant Isaac has argued, global governance efforts tend to have both economic and social objectives.[16] They often aim to improve the efficiency of the market system by increasing the consistency of rules and behaviour by states, firms and individuals. However, they also attempt to ensure that the same market activity occurs in a way consistent with the political preferences and social expectations within and across the jurisdictions involved.

What need is there for global governance of technology? Why is *global* governance necessary? Why can't each jurisdiction simply create its own rules, uniquely adapted to local values, needs and economic conditions? This is an important question.

One answer relates to economic interests and the structure of the global economy.

In a globalized world where, for both economic and environmental reasons, companies tend to specialize their production and engage in global trade according to comparative advantage, goods and services produced by, or incorporating, emerging technologies will be traded across borders. In fact, they already are. Harmonized regulatory standards are an important aspect of reducing barriers to trade and allowing more countries to realize benefits from both production and consumption.[17]

Being able to access multiple markets is also important for technologies that require significant capital investment to develop. Some technologies, such as nuclear technologies, and 5G network technology, are so expensive to develop they require a minimum market size that is larger than most countries.[18] Indeed, these technologies can be critical parts of national infrastructure and have national security implications.

In a world fragmented by differing regulations, it could be far more expensive, or not make sense at all, for certain new technological systems to be developed. And, if such systems are produced, they are likely to emerge from players embedded within the largest markets, compromising the ability of smaller countries to produce globally influential firms or technologies.

The digitalization of the global economy also allows services to be traded – services that may rely on emerging technologies. Ensuring that consumers are both able to access these services and have recourse in the event that they cause harm, is likely to require governance alignment.

Another answer relates to the way in which emerging technologies might cross borders outside of the global trading system.

Several emerging technologies have impacts that can cross borders without human intervention. Most notable among these are large-scale environmental interventions such as geoengineering, or biological interventions such as gene drives. While this fact doesn't necessarily require that all regulations be harmonized, it does imply a need for global governance processes to help minimize any cross-border impacts, such as when AVs cross borders.

Inputs, networks and infrastructure related to emerging technologies are increasingly cross-border. Processing power, data storage and the sources of data used to create value may all exist in a different jurisdiction from the user or the device being governed. Without alignment across jurisdictions, significant opportunities may be lost.

This is not to imply or argue that all technology governance must be global. It is important for many reasons that regions, states and cities are able to respond to the specific social or economic needs of their citizens. National security, food safety and healthcare are obvious examples.

There are also advantages to having governance systems that are not entirely homogenous – including improved system resilience, a lowered risk of contagion and the opportunity for competition and "race to the top" dynamics. And, of course, in many contexts there are only small efficiency losses created by having different systems – witness, for example, the (admittedly, relatively small) variation in driver licensing regimes among the different US or Australian states, which does not inhibit drivers from crossing borders.

Nevertheless, global governance processes are valuable even if they do not result in entirely harmonized systems. This is because the process of exchanging ideas and negotiating rules is in itself useful, increasing the possibility of governance transfers and constructive collaboration.[19]

1.2 Technology governance frameworks

Assessing or making sense of the landscape of technology governance requires adopting a particular lens through which to view the myriad activities occurring across jurisdictions and technologies.

Six clarifying questions are particularly useful in building up a picture of the governance landscape:

1. *Who is responsible for, or doing, the governing?*
2. *What set of technologies are implicated?*
3. *In what ways are governance approaches aligned?*
4. *When does governance occur?*
5. *What mechanisms incentivize or drive collaboration around governance?*

1. Who is responsible for governing? The role of public vs. private governance mechanisms

One way to analyse and understand the landscape of global emerging technology governance is to consider the sources of governance mechanisms and needs. The dominant sectors in terms of how rules, norms and incentives are created derive from government, the private sector and civil society. Using this distinction, different governance mechanisms can be public

(created primarily by and enforced by governments) or private (originating from and mediated by the private sector). The former can often arise from civic pressure, as a result of the role of civil society in this process..[20]

Public-sector governance of emerging technologies often involves, but is not limited to, the development of legal or regulatory instruments to guide their use or testing. They sometimes rely on robust data to support decision-making. Take, for example, national and subnational regulation over the use of autonomous drone technology. In 2017, the Government of Rwanda began developing performance-based regulations that allow for firms to test new unmanned aerial systems as long as they can prove they meet minimum safety requirements.[21]

On the private-sector side, a prominent and powerful example is that of standards organizations such as ISO, Institute of Electrical and Electronics Engineers (IEEE) and International Electrotechnical Commission (IEC). These all develop and distribute standards for electronic products and systems, integrating and influencing country-level standards and governance by engaging national bodies and professional members.

While such standards are "merely explicit norms in technical language" set by private organizations, and bodies such as the IEC cannot compel compliance, they have power through multiple pathways. [22] These include the widespread adoption of standards by manufacturers; trust built with users through the use of certifications or labelling; the desire for interoperability; their use by courts as indications of effective methodologies; their use by insurance firms to gauge risk and thus provide market incentives for adoption; and reference to standards in laws and regulation that makes them mandatory.[23]

However, as discussed below, emerging technologies – and therefore the governance issues associated with them – transgress traditional boundaries. It is therefore important to adopt an approach to technology governance that acknowledges how these issues blur the boundaries between the public and private spheres.

In some cases, governance is the outcome of extensive dialogue and cooperation between public and private rule-making bodies. For example, Singapore's standards for the testing and deployment of autonomous vehicles, released in January 2019, were led by Singapore Standards Council's Manufacturing Standards Committee, but developed in collaboration with representatives from the autonomous vehicle sector, research and education institutions, insurance and government agencies.[24]

2. What set of technologies are implicated? Distinguishing between "cross-cutting" and "technology-specific" governance

Another way of viewing the landscape of technology governance categorizes challenges according to how related they are to individual technological characteristics and capabilities.

There are a range of governance opportunities, challenges and instruments that are linked to managing particular technologies, subsets of technologies or a specific domain. These tend to be related to the idiosyncrasies or possibilities opened up by new sets of capabilities, or new ways of achieving existing ends.

For example, while both unmanned aircraft systems (UAS) and piloted aircraft involve flying objects that can transport both things and people, the size, cost, autonomy and flight characteristics of the former demand special regulations for managing their flight. Thus, the governance of the autonomy of UAS is rather technology-specific, rather than an issue that can or should be resolved at a higher level across multiple technologies. The result is a set of rules, authorities and norms expressly aimed at managing the use of UAS.

A second category involves governance issues that are more-or-less technology-agnostic. These tend to relate to the very process of incorporating diverse technologies into a changing social context, or the provision of what might be seen as "public governance goods".

For example, rules or resources that support access to new technologies for minorities or vulnerable groups fall into this category, as do overarching standards that ensure the environmental sustainability of new approaches. Rules and norms around privacy and data-sharing can be applied to multiple technologies that rely on data which may be personally identifying.

Public and private forms of governance are relevant to both cross-cutting and technology-specific governance concerns. However, the nature of cross-cutting issues means they are more likely to be debated, ruled and legislated on through public systems, while technology-specific issues tend to, at least at first, sit in within the domain of private forms of governance.

3. In what ways are governance approaches aligned? Vertically integrated and horizontally integrated technology governance

A third way of framing technology governance is to observe how connected policies, standards and regulations are vertically and horizontally integrated among actors and/or governance levels.

Vertical integration implies coherence among the different layers of decision-makers at the local, national, regional and global levels. While vertical integration is challenging to achieve, even for public governance in a single state, it tends to be a function of institutional policy-making structures and is influenced by the effectiveness of communications across different levels of government.[25]

Horizontal integration refers to the alignment of governance approaches across government departments; for example, integrating environmental, transport and infrastructure policies so that they don't conflict with one another. Another form of horizontal integration refers to aligning jurisdictions (e.g. among different cities and states), across multiple technologies, between rule-makers and the communities that could be affected and across the different sectors.

Horizontal integration is in many ways harder to achieve than vertical integration, as it requires the creation of

common languages across cultures and disciplines and government levels. Having multiple levels of government (municipal, state, national) can dramatically expand the number of actors involved and thereby greatly increases the complexity of the policy-making process.[26]

4. When does governance occur? Ex-ante vs. ex-post technology governance
A final framework that is useful for understanding the landscape of technology governance is to consider the point in the life cycle of a technology or its application to which efforts to govern it are applied.

Ex-ante governance approaches seek to influence behaviour and avoid or prevent risks by putting mechanisms in place *before* technological applications and any associated challenges emerge.

A common strategy in this category is risk analysis, which attempts to assess and manage risks by relying on expert testimony, scientific data, information from pilot programmes and small-scale experiments, and techniques such as scenario analysis.[27]

A second ex-ante strategy that is often invoked to manage technologies is the use of the precautionary principle. This principle argues that where risks are both high and uncertain, the deployment of that technology should be relatively slow in order to maximize control. This principle can be seen in both popular discourse and the regulatory approaches to nuclear technologies and genetically modified organisms in different jurisdictions. The precautionary principle is particularly evident in the European Union, where it forms part of Article 191 of the Treaty on the Functioning of the EU with regards to environmental risks.

By contrast, *ex-post* governance seeks to manage risks after they arise. For example, the establishment of liability is a strategy that acts only after a harm is realized, but which nevertheless governs both the emergence and impact of a risk related to a technology. Liability regulations – such as product liability laws – provide incentives to minimize harms and create mechanisms for compensating those injured.[28]

Another risk management strategy is to build mechanisms of resilience into systems in order to increase the ability to plan for, recover from, and adapt to adverse events.[29] These include mandatory review periods and sunset provisions to force lawmakers to reconsider whether governance mechanisms are still appropriate; post-market monitoring to rapidly detect if risks are emerging; post-approval recall; building redundancy into systems; and creating "kill-switches".[30]

5. What mechanisms drive collaboration on governance? Governance through hierarchy, networks, negotiation, competition and cooperation
A final lens that is useful for understanding the landscape of global technology governance today is one that distinguishes between different drivers and modes of governance.

As stated above, it's easy to distinguish between public and private modes of governance, which often leads to simplistic frameworks around the impact of "hierarchy", referring to the power of governments to impose rules, versus "markets", which reference the role of competition and incentives for behaviour that flow from the private sector. However, this disregards the overlap between these modes and the complex interplay between sectors.

In addition to hierarchy and markets, therefore, we might add "networks", as suggested by Tanja A. Börzel and Karen Heard-Lauréote.[31] In their usage, networks are "non-hierarchical modes of coordination constituted by mutual resource dependencies and/or informal norms of equality among the actors involved". Networks, in this case, involve both public and private actors where their status is roughly equal, and agreements are voluntary and collectively binding.

A similar model is that proposed by Ingeborg Tömmel and Amy Verdun, who use case studies from the European Union to distinguish between four modes of governance: hierarchy, relating to the implementation of legislation through established power structures; negotiation, which is the process of managing interests and building consensus across states and actors; competition, which creates pressure in favour of alignment due to the ability for companies to make choices between jurisdictions; and cooperation, the practice of coordination and voluntarism.[32]

1.3 The dynamics of emerging technology governance

The attributes and effects of the technologies driving the Fourth Industrial Revolution require both governments and enterprises to develop new forms of governance. There are four dynamics that are particularly troublesome for current systems of governance.

The first is the scale and rate of technological diffusion. The sheer pace of technological development renders traditional policy-making cycles and processes inadequate. Emerging technologies take for granted the digital networks of the third industrial revolution, which enables them to mature at scales impossible in prior eras of technological transformation. It also means that they have more immediate cross-border impacts.

Second, the same digital underpinnings and shared knowledge networks that increase the rate of diffusion are also driving convergence between technologies and making them relevant across diverse sectors. Take, for example, the convergence of biological and digital technologies that are enabling products which are traditionally grown to be engineered, and vice versa.

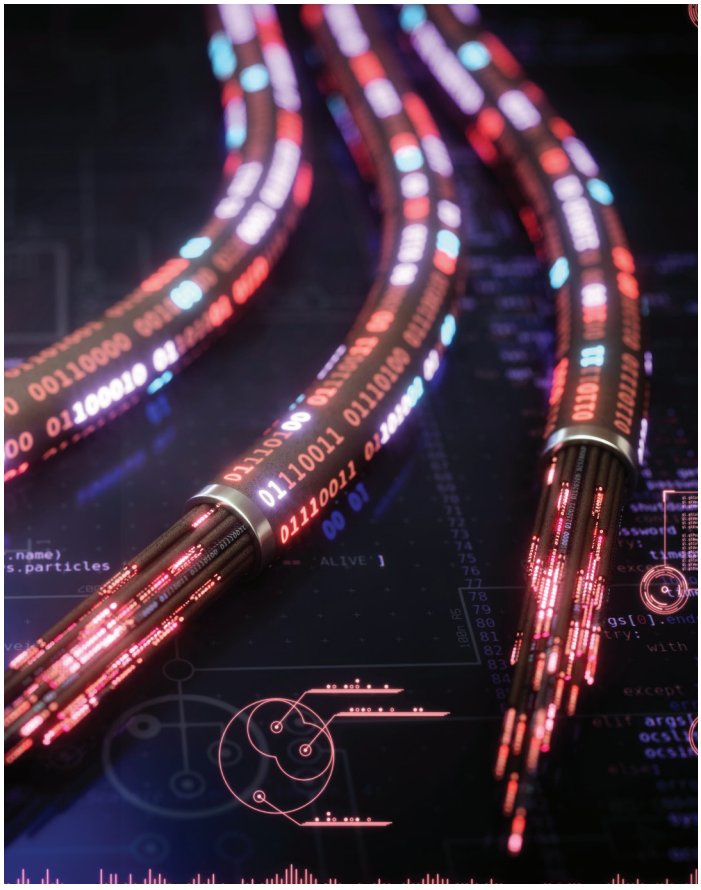
Third, the personalized nature of many emerging technologies allows them to be rapidly integrated into social systems and daily life for large numbers of people, making it difficult to govern them after they have become widely diffused or ingrained. The rapid rollout of ride-sharing and short-term letting platforms are good example of this – by the time many city governments started to push back against such platforms for breaching existing governance mechanisms, large numbers of citizens had begun to rely on them for their daily activities or flows of income, creating powerful interest groups on the side of the companies that created them.

Fourth, emerging technologies have a political nature, embodying values, assumptions and principles that influence who they affect in society, and in what ways. How individuals, companies and governments invest, design and use technologies is affected by the experiences, assumptions and ideologies of the developers creating them, as well as the norms and values in the context within which they are developed and deployed. For example, whether AI systems have racial biases will be influenced by the choice of code, the data used to train the system and the population on which it is used.[33]

Finally, emerging technologies are, almost by definition, highly uncertain in terms of their influence and successful diffusion. As discussed above, this makes it difficult to manage risks in advance without compromising the opportunities they represent. Yet waiting until uncertainties are resolved is also challenging, as technologies may already be integrated into social systems. This is known as the Collingridge dilemma: "When change is easy, the need for it cannot be foreseen; when the need for change is apparent, change has become expensive, difficult and time-consuming."[34]

These dynamics complicate the process of technology governance and exacerbate the challenges of policy lag, where appropriate governance significantly falls behind the introduction of new technologies or business models; and policy decay, where policies lose their relevance over time as technologies advance and contexts shift.[35]

Managing these dynamics requires more agile governance methodologies, which the Forum explored in its 2018 white paper *Agile Governance: Reimagining Policy-making in the Fourth Industrial Revolution*.[36]



An overview of agile governance

Adapted from *Agile Governance Reimagining Policy-making in the Fourth Industrial Revolution*.

The concept of agile governance aims to shift the manner in which policies are generated, deliberated, enacted and enforced in the Fourth Industrial Revolution. Pairing these terms sets the expectation that governance can be, and some would argue should be, more agile to keep pace with rapid changes in society – driven significantly by the rapid development and deployment of emerging technologies. Policy-makers must become more proactive in shaping these developments.

While more timely experimentation and decision-making may be warranted in many cases, agile governance does not privilege speed over the duty of public and private governance processes to empower and protect those they serve. Agile governance in its ideal form does not sacrifice rigour, effectiveness and representativeness for speed. In fact, agility can also enable policy-making that is more inclusive and "human-centred" by involving more stakeholders in the process and allowing for rapid iteration to meet the needs of the governed. Agile governance can also ensure long-term sustainability by creating mechanisms to constantly monitor and "upgrade" policies governing emerging technologies, as well as by sharing the workload with private sector and civil society to maintain the relevant checks and balances.

Agility in governance can be enabled by various approaches. Systems and design thinking are two methods that have demonstrated their capacity to tackle complexity, prioritization issues, integrate human-centric views and insights from early prototyping of policies. Given that governments are often criticized for being slow reactors to technology innovation, reframing this approach as one that seeks to navigate the pace of change through adaptive, human-centred, inclusive and sustainable policy-making is an important conceptual shift towards long-term value-based policy design through system and design thinking. System and design thinking go hand in hand as fundamental methods in the reconfiguration of policy-making in the Fourth Industrial Revolution.

The aim to govern in a more dynamic and agile manner can broadly be conceptualized in two ways: efforts to work around existing governance structures; and efforts to change the current policy-making system itself. The first operates through agile optimization, experimentation and workarounds of existing governance structures and institutions and is a less onerous exercise. The second approach is through broad and all-encompassing reforms of existing governance institutions, changing who makes decisions, how they make those decisions, and creating new sources of authority for governance structured to be more agile and human-centred. Few stakeholder groups, if any, have been able to execute this approach.

Part 2: Sketching the technology governance landscape

2.1 An overview of global technology governance in 2019

Imagining the global technology governance landscape
If you were presented with a giant, pictorial representation of the state of global governance for emerging technologies in 2019, what might you see?

Based on expert interviews and workshop discussions among the World Economic Forum's Global Fourth Industrial Revolution Councils and other leading experts, here are some characteristics of the global governance landscape that you might notice, and which are deserving of in-depth analysis and confirmation.

First, you would note that the governance landscape is **relatively sparse**, particularly on the global level. The highest layer, representing settled agreements among multiple countries, would have the most white space. You'd see that global governance is obliquely dominated by provisions around trade, financial and intellectual property regimes: Yet very few of these would be specifically focused on the latest emerging technologies, and all would seem a bit out of date.

Second, you'd observe that the national and subnational governance that does exist is rather **disconnected** – both horizontally between departments, disciplines, countries and technologies, and vertically from local to global levels.

Third, you might remark on the **geographic distribution** of governance activities. It would be quite obvious that the Global South was being ignored in the majority of the governance activity that is occurring. There would be several bright spots in smaller, agile economies, such as Singapore, the UAE, Rwanda, Estonia, Lithuania and Switzerland – and China would be shining brightly.[37]

Fourth, despite the unevenness and disconnectedness of governance activities, you'd see **patterns emerging** in the issues being addressed. As discussed at length in section 2.2, topics such as privacy, security, data-sharing, interoperability, access, employment and the environment recur.

Fifth, you'd see several **powerful cities** in the governance landscape, and a significant amount of city-level activity when compared to higher jurisdictions such as states or nations. Thanks to the fact that they make many critical decisions around the built environment, cities are the dominant forces in autonomous vehicles and integrated transport systems, IoT, drone technologies and data-sharing.[38]

Sixth, if you were to zoom in and look more closely at the quality of the governance provisions illustrated, you'd be struck by the **early stage of development** of most of the rules focused specifically on emerging technologies. The map you're observing would be covered in experiments, pilots, labs and initiatives that come within a framework of regulatory inheritance[39] – but relatively few new settled standards, laws, regulations or supervisory authorities.

Seventh, you'd notice that many of the governance mechanisms have been created almost **independently of traditional rule-making mechanisms**. If you traced the lineage of the rules and norms that do exist, you would see lots of executive orders, fast-track procedures, informal coalitions or parliamentary committees, rather than established institutional decisions.

Eighth, you might recognize that there is a large amount of **high-quality work being undertaken by standards organizations** that is still unreleased but could soon be significantly influential and provide much-needed guidance to governments.

Finally, you would perceive that many **corporate policies and practices** intersect and often conflict with government

regulations, underscoring the need for multistakeholder cooperation and opportunities to co-design and build policy frameworks and protocols.

How is this landscape changing over time?
In addition to asking experts their thoughts on what characterized the landscape of global governance in 2019, we sought to understand how this picture might shift over the coming five years.

Caution and concern about the future of global cooperation revealed little consensus about the direction for global governance. However, several themes and drivers emerged that could constitute "weak signals" of the future.

1. Local imitation
As cities and other jurisdictions experiment with new governance approaches, they are motivating others to borrow elements or even adopt their approach wholesale. These tend to be non-hierarchical and based on market-based or voluntary shifts towards aligned models.

In some cases, this is a matter of market influence, resulting in regulatory diffusion. A classic example in technology governance is the influence that the state of California has over vehicle emissions rules. Given how large and important a market for vehicle sales California is (more than 10% of the total US market), emissions regulations set by the state government have a measurable impact on the emissions standards in other jurisdictions.[40]

In other cases, it is simply a question of efficiency, lack of local capacity or unwillingness to go through the process of creating entirely new governance regimes when a good example is available.

2. National influence
There continues to be significant global governance influence flowing from national governments. This tends to be more hierarchical, particularly among states with significant market power.

Perhaps the most obvious of these are provisions for technology governance within trade agreements. For example, the "new NAFTA" U.S.-Mexico-Canada Agreement (USMCA), contains provisions that imply restrictions around the ability for signatories to refuse the import of genetically modified agricultural goods.[41] Similarly, aid agreement stipulations, agreements about international security and geopolitical signalling were all seen as influencing factors for the global governance of emerging technologies.

3. Platform power and corporate influence
A third critical driver was the power of individual firms to set and influence governance norms, particularly the large tech platforms and industry-dominant multinational corporations (MNCs). MNCs can often fall beyond the sphere of public international law and the norms that bind local governments. In some cases, such as AI, company collaboration has been a signal to regulators that industry players are aware of the challenges and can adequately self-govern. Coalitions of companies in the form of industry gatherings were seen as remaining relevant, with lobbying and alignment among firms in Brussels and Washington DC as a particularly important area to watch.

However, social pressure and brand exposure were also viewed as becoming more important factors for corporations, along with the exchange of senior staff among firms and factors linked to the need to work across jurisdictions to develop system-scale technologies.

4. Regional efficiencies
Regionally driven governance is seen as rising in importance. The influence that the EU's General Data Protection Regulation (GDPR) has had on other jurisdictions is significant, and many experts interviewed believed it has been undervalued as a driver for global governance. Similar exercises in the ASEAN (Association of Southeast Asian Nations) region will be important to watch as it aspires to develop a single digital market.

5. The power of standards
As discussed above, some respondents noted that the next few years will see quite a few critical standards being released from the most influential standard-setting bodies, particularly the IEEE, IEC and ISO. While current assessments of the state of global governance show that many initiatives are currently "in progress" or "under discussion", the landscape may look significantly different once the current standards under development emerge from their preparatory phases. In this way, the consensus nature of standards is a powerful tool for global alignment.

6. Supranational authorities
There are also a wide range of existing international collaborations, processes, institutions or agreements that have power and influence across multiple jurisdictions and stakeholder groups related to technology. Examples include the World Trade Organization (WTO) and the International Telecommunications Union (ITU), as well as treaties such as the Cartagena Protocol. Between these examples are covered global trade, digital infrastructure development and international biosafety.

Some experts pointed out, however, that many supranational bodies are currently suffering from funding crises, falling global legitimacy or both. It is perhaps telling that, from a pool of approximately 200 experts, not one proposed a new, supranational, treaty-based organization to take on the challenge of global technology governance.

7. Informal cooperation mechanisms
Finally, it was recognized that there has been an increase in the number and quality of informal processes related to technology governance. These include the numerous activities and structures initiated by the World Economic Forum, activities dedicated to specific technologies such as the ITU's AI for Good conference series, and bodies such as the UNSG's High-Level Panel on Digital Cooperation. Proposals for new mechanisms included the call for a Governance Coordinating Committee by Wendell Wallach and Gary Marchant.[42]

Of all these mechanisms, the prospect for informal cooperation mechanisms were considered to be the most important.

How do research scientists experience the governance of emerging technologies?

Outcomes from the Frontiers Survey

We surveyed more than 100 top research scientists focused on emerging technologies across the fields of AI, robotics, blockchain, big data, precision medicine, mechanical engineering, sustainable cities, public health and computer science. We asked them three important questions:

1. First, what are the most powerful external influences affecting your research?
2. Second, what internal or lab-based influences affect your research?
3. Third, what personal factors or influences mattered the most in shaping your research?

Predictably, funding has by far the biggest impact. *Governance and regulatory issues were critical factors for less than 15% of respondents.*

Internally, resource availability is the dominant factor for more than half of respondents, followed by institutional research priorities. Of note is the fact that interest from colleagues and students was the next most influential factor, with 50% of respondents saying that this was material to them.

Personally, more than 85% of respondents said that their own interests were dominant. But 50% said that their reputation was a guiding factor, with more than 40% saying that ethics played an important role, and just under 40% saying that career ambitions were a key consideration.

Approximately 13% said that personal financial considerations were taken into account when determining what, and how, they would research, and only 1.3% said that faith or religious convictions played a role.

2.2 Priority cross-cutting issues in technology governance

The landscape of technology governance today is home to several common challenges that are being tackled in different ways across jurisdictions and technological domains.

Based on interviews and workshops with experts between February and August 2019, the following list reflects the most important governance issues identified across six technology areas: AI and machine learning; drones; precision medicine; IoT; autonomous vehicles; and blockchain. They are:

1. Delivering privacy and security while enabling data collaboration
2. Designing interoperable technologies and systems
3. Ensuring access and inclusion, particularly for vulnerable groups
4. Driving increased employment and skills development
5. Managing the direct and indirect environmental impact of new technologies

These "cross-cutting issues" were identified through comparative research by the Global Fourth Industrial Revolution Council Fellows and Arizona State University (ASU) researchers using two complementary methods.

First, these issues were identified by examining the frequency with which governance concerns recur as specific issues within and across the six emerging technology areas mentioned above. To assess this frequency, the Forum-ASU research team analysed six detailed governance maps produced by literature review and expert feedback. They then coded linked issues to identify the most commonly appearing topics.

Second, the five most frequently occurring issues were subjected directly to expert review in order to validate whether any additional topics may be relevant at the cross-technology level.

2.2.1 Delivering privacy and security while enabling data collaboration

All governance issues require finding a balance between competing concerns, which are often dynamic in nature. One such challenge involves protecting against the risks of personal-data misuse while enabling relevant data to be the basis for improved decision-making and knowledge that benefits society as a whole.

The dangers related to the misuse of personal data – especially health and financial data – cannot be overstated and are very much at the centre of the public debate right now. For example, in the past year alone, major hotel chains and financial service companies have been hacked, putting over half a billion people at risk.[43] Such breaches have led to exposed credit cards, passport numbers and other personally identifying information. The corresponding governance regimes would need to help improve rules and practices around data privacy, data ownership, consent and data security. In fact, 51 chief executive officers sent a letter to the US Congress asking for data privacy regulation.[44]

However, to err too much on the side of protecting all data and heavily restricting its use would produce a set of offsetting, avoidable harms resulting from the non-use of data. The cost of data non-use includes the potential loss

of human life and property, thanks to poor decision-making due to insufficient and inaccurate data.[45] The application of shared, cross-linked data could be a significant help in battling emissions, traffic congestion and disease, not to mention aiding in the delivery of government services. The governance of data usage – especially how datasets are linked to one another for maximum utility – is even more important than regulating the sets of data themselves. As the World Economic Forum's recent report *Data Collaboration for the Common Good: Enabling Trust and Innovation Through Public-Private Partnerships* put it:

> "When data is shared, linked and combined across sectoral and institutional boundaries, a multiplier effect occurs. Connecting one bit with another unlocks new insights and understandings that often weren't anticipated."[46]

The upside from getting this balance right is significant. McKinsey recently identified seven sectors, including healthcare and consumer finance, where they argue that successfully connecting and integrating data across institutional, organizational and geographic boundaries could lead to the addition of $3 trillion per year in economic value by 2020.[47]

It is therefore essential that data is shared and used in ways that ensure its use is fair, just and legal.[48]

The need for privacy, data rights and security

Preventing the misuse of data requires a) keeping it secure and b) ensuring that it is used in accordance with a user's rights and consent.

Cybersecurity is a complex, cross-cutting governance issue in its own right. For governments and organizations to build and maintain trust in the digital domain, they must prioritize cybersecurity as a critical aspect of their business strategy, innovation and governance. There is even a compelling argument for treating cybersecurity as a public good in order to make sure systems are robust for all citizens and that "the costs do not become a deciding factor in determining access".[49]

For public and private organizations unable to engender trust through secure systems, it will be far more difficult to receive and handle private data, hampering their ability to add value in the Fourth Industrial Revolution. Failing to address cybersecurity as a fundamental aspect of development undermines the opportunities to scale the beneficial outcomes of technologies.

Cybersecurity lapses can also cost businesses substantial value. Take, for instance, Verizon Communication's 2017 acquisition of Yahoo. Thanks to Yahoo's disclosure of two data breaches immediately in the year prior to the deal's completion, affecting more than a billion of its customers,[50] Verizon reduced its acquisition price by $350 million – from $4.83 billion to $4.48 billion. Overall, the cost of cyber breaches is projected to double from $3 trillion to $6 trillion by 2021.[51] Beyond the financial impact for organizations, personal data can be used to infiltrate individuals' systems, establish false identities and steal payment or credit information. The result is a degradation of a system that requires both scale and trust to provide widespread benefits.

Even if the services you use and organizations you interact with can keep your data safe, how are they allowed to handle it? Privacy International argues that data rights are of primary importance:

> "Data rights give people authority over their data. These rights can be quite powerful: they offer the right to access, to change, to move or to delete data; the right to know who's collecting it, where it is, where it's going, who has access to it, for what purposes."[52]

Data rights are also intertwined with questions about data ownership. As public personalities and activists such as William James Adams Jr. (aka will.i.am) have argued,[53] the concept of ownership extends data rights into the arena of property rights, allowing individuals to charge third parties for the use of their data – something that, according to a former social media lead counsel, could be technically enabled by systems that promote concepts such as "self-sovereign identity".[54]

Another important concern relates to consent. Consider the new post-GDPR[55] routine of visiting a website – which is visible on the GDPR site itself – and being presented with a consent form asking you to consent to cookies that can track your information and share it with third-party sites.

How informed is such consent? Is it useful when the user's intention is to visit that site only a single time? And how can policies account for the way in which increasingly complex technologies shift the threshold for what it means to give informed consent? These are not new questions in law. However, the advent of more sophisticated algorithms and data systems – for example, those deploying machine learning or based on distributed ledger technologies – make it increasingly challenging for consumers to understand the ramifications of their choices to share data. The secondary and tertiary use and impact of that data may never be clear.

Security, rights and consent are all cross-cutting governance issues that require investment. The EU GDPR has gone a long way towards ensuring all of these – creating new benchmarks, requiring processes to be established, and setting significant penalties for breaches. For example, established in Article 17 of the GDPR, users can request data that companies gather about them and, in some cases, ask for that data to be deleted.[56]

The GDPR punishes the misuse of data and, so far, this has led to millions of dollars in fines and has given more power to national organizations to fine companies for transgressions.[57] While GDPR is a European regulation, it has had global impact because nations and private services are tied together through ever-expanding global networks. Nations are working to keep pace, and some are succeeding, such as in Japan and Israel, where privacy and data governance are now fully compliant.

The need for data collectives and sharing for the common good. It is not straightforward to share information while keeping it safe from misuse.

Removing vital identifying information – such as names and addresses – from data is far from a perfect solution. Anonymized and/or pseudonymized location data can be used relatively easily to re-identify individuals within a larger dataset.[58] Latanya Sweeney proved almost 20 years ago that, in the United States, simply possessing someone's postcode, birthdate and sex – three pieces of information – allows the person to be identified in 87% of cases.[59] Current capabilities are much more sophisticated and far more data is being stored.

Nevertheless, the value of data collaboration demands that solutions be found. The Forum's work in this area demonstrates that there exist five critical enablers of public-private data collaboration: achieving stakeholder alignment at the outset of a partnership; establishing responsible data governance; delivering insights that are accurate, unbiased and explainable; providing decision-makers with the tools, building processes and support to act on new insights; and ensuring long-term economic sustainability.[60]

As an example, the World Health Organization's announced in 2019 a new concept called the EPI-BRAIN (Epidemic Big Data Resource and Analytics Innovation Network) initiative, designed to create a sustainable, shared, accessible and integrated data innovation environment to reduce the impact of infectious disease outbreaks through forecasting and predictive analytics. One dimension of the initiative will be the need for trustworthy and accountable access to population-movement data at scale. This multidisciplinary and multistakeholder community will be launching in 2019.

Privacy and public security

Another complex tension related to privacy and security is the extent to which technological systems should privilege the individual privacy and security of users through the use of strong encryption, or whether such individual protections should be weakened to allow security services to have access to these private spaces in order to monitor, dissuade, anticipate and prosecute criminal behaviour.

Proponents of individual privacy, such as Human Rights Watch, argue that the cost of systemically weakening cybersecurity through the use of "backdoors" to encrypted systems is far greater than the threat of criminal actors "going dark".[61] Governmental departments can hold the opposing view, arguing that limiting public right of access equates to "law-free zones", pointing out, for example, the human cost of a Mexican drug cartel using encrypted systems to target and murder police officers.[62]

Governance trends seem to favour the argument that invokes national security and have resulted in two strategies.

The first strategy focuses on the creation of "backdoors". Australia's Assistance and Access Bill 2018[63] amended existing telecommunications legislation, allowing Australian government agencies to apply and obtain a warrant, requiring a technology company to allow the agency access to information linked to an individual or group. Amendments to the legislation specified that such intercepts should not amount to systemic weakening of the service, but it remains to be seen how this balance could be technically achieved.

The second strategy simply outlaws the use of encrypted services. Encrypted messengers WhatsApp and Snapchat are banned in China, while China's most widespread messenger, WeChat, does not possess end-to-end encryption. Signal is outlawed in Egypt and Telegram is banned in Russia.[64] The US,[65] UK[66] and Germany[67] have all discussed effectively banning end-to-end encryption, the latter by simply legislating that providers record all communications and provide plain-text transcripts to authorities when legally required.[68] The importance of this issue to governments (and citizens) demonstrates that privacy and public safety are two sides of the same coin.

The challenges and opportunity ahead

Resolving these three critical sub-issues – how to ensure privacy, how to share data for the public good and how to balance both individual and group security – are public policy issues that recur across the domains of emerging technologies.

This is naturally true for emerging technologies heavily integrated into public environments – such as autonomous vehicles, IoT devices and drones. But data-sharing and privacy issues are equally critical for precision medicine and AI. And while distributed ledgers are often offered as the solution to data-sharing challenges, they also embody similar tensions between security, anonymity and transparency.

2.2.2 Designing for interoperable systems

The second pervasive governance issue is interoperability. Interoperability is relevant from infrastructure to administration. For data to be employed as a common resource, both the technologies themselves and the rules that govern them need to work efficiently and effectively across multiple jurisdictions.

Collaboration of this sort requires governance regimes, technological systems, organizations and individual devices to possess the ability to interact and share information. To achieve this, it is not necessary for systems or approaches to be identical in all jurisdictions. Rather, systems should be both broadly congruent and able to communicate, rather than at odds with one another.

At a minimum, emerging technology systems should be able to exchange information using common data formats and communication protocols (syntactic interoperability).

Ideally, they should be able to directly interpret data from one another to accurately and consistently produce benefits for users (semantic interoperability). Together, these concepts constitute technological interoperability, a valuable outcome even beyond this context.

Technological interoperability is, however, insufficient by itself. To ensure that global governance is achievable, policy and governance regimes also need the capacity to exchange information and data among themselves, concerning both specific applications of rules ("Is that drone allowed to fly in my airspace?" and the effectiveness of their approaches ("Is my flight verification protocol as accurate as yours?"). Again, in an ideal world, different national policy regimes would be designed with semantic interoperability, able to collaborate and otherwise interact in ways that consistently produce similar results, without requiring that the governance regime be identical. This is what we refer to as governance interoperability.

Such governance interoperability does not mean nations must sacrifice all of the context and nuance of their specific cultural and ethical claims on what a technology should do in a specific scenario (for example, how an autonomous car should weigh the decision to either hit a pedestrian or kill the driver if no other options are available).

The benefits and risks of interoperability

Just as privacy needs to be balanced against the need to use data for the common good, the challenge of interoperability raises dynamic tensions. For instance, while interoperable systems enable scale and lower the cost of access, they also increase systemic vulnerabilities, create both winners and losers among the users of differing standards, and can lower incentives for the creation of entirely new systems.

Benefits	Costs and risks
Enables scale for those already or naturally compliant, and expands effective market size for compliant products and services	Depending on how interoperability is enforced, can lower profits for enterprises reliant on "lock in" to a closed network
Can lower cost of access and use, and hence cost of training and upgrades	Can scale fragilities and weaknesses of systems
Lowers cost and complexity for developers and intermediaries creating new products and services	Enhances risks of contagion
Makes reporting and analysis easier and lower cost by enabling data-sharing, reducing conflict between data formats and lowering error rate, and enabling learning across the system	Involves costly – and time-consuming – coordination to agree on standards for interoperability "top down"
Increases agility, flexibility and responsiveness, particularly in crisis situations	Involves costly investment for existing systems that need to be brought into compliance
Enables trade in goods and services by enabling regulatory approaches to be based on common technical capabilities and structures	Discourages disruptive breakthroughs that work on entirely new protocols or standards
Lowers switching costs for users, increasing competition for products and services compliant with the standard	Biases markets towards the "winning" or dominant standard
Enables the movement of people and data across borders	Can result in "lowest common denominator" approaches being accepted

Technological and governance interoperability

Technological and governance interoperability can be tackled together.

As an example, take the European Interoperability Framework (EIF), a European Commission instrument focused on the interoperability of public services.[69] This framework, with its 47 recommendations, provides guidance on how EU member states should design interoperable digital public services if they want to maximize benefit. The framework's three goals are to:

1. Support European public administrations to design and deliver seamless European public services that are, digital-by-default, cross-border-by-default (i.e. accessible for all citizens in the EU) and open-by-default
2. Provide guidance to public administrations on the design and update of national interoperability frameworks (NIFs), or national policies, strategies and guidelines promoting interoperability
3. Contribute to the establishment of the digital single market by encouraging cross-border and cross-sectoral interoperability for the delivery of European public services

Without such opt-in interoperability opportunities, there is the risk that, as multiple European jurisdictions invest in both technological systems and new rules to govern them, they will end up with "isolated digital environments and consequently electronic barriers that may prevent public administrations from connecting with each other, and citizens and businesses from identifying and using available digital public services in countries other than their own".

The importance of standards as governance mechanisms that support interoperability

A powerful driver of interoperability is the creation and acceptance of standards, which can exist formally at the technical levels or informally through the spread of information and the emergence of dominant practices.

Standards are frameworks of specifications that are generally accepted and widely used throughout an industry or other domain. Typically, these have been developed and approved by a recognized organization.[70] They can be propagated in many ways – by law (as mandatory standards), through financial systems such as insurance requirements, or through market power. Standards speak to industry stakeholders and represent a form of participative governance by engineering bodies connected to areas requiring expertise that governments often lack.

Standards are important beyond their role in supporting interoperability. They are all around us in everything from food quality to technical infrastructure. They can raise levels of quality, safety, reliability and efficiency while reducing costs. Partnership with governments can give industry stakeholders a role in making sure standards address social needs and don't skew too heavily towards the industries developing them.

The emergence of standards, however, is challenged both by the time and complexity taken by formal standard-setting processes, and by the fact that standards are rarely open and need to be purchased in order to support their development, marketing and intellectual property protection.

The challenges and opportunities ahead

Supporting the principle of interoperability, investments to reduce the time in which standards can be developed, and efforts to open up standards so that they are as widely used and freely available as possible would significantly accelerate governance efforts across the full range of emerging technologies.

Indeed, interoperability is the first and possibly most important governance issue facing the use of blockchain and other distributed ledgers. It is also cited as a critical issue for IoT, autonomous vehicles and precision medicine. Interoperability will also shape the future of AI governance and its use as a private-sector competitive advantage.

2.2.3 Ensuring access and inclusion

Governance and rule-setting exists, in part, to solve problems that no individual is capable of tackling independently and manage resources that no individual can steward on their own. In this way, good governance helps groups resolve or avoid issues related to uncertainty or misaligned incentives in order to create a present and future that is closer to the perceived ideal.

One particularly important role of governance is closely linked to a critical role for the majority of governments around the world: ensuring that the maximum number of citizens have the opportunity to participate productively in social, economic and political life.

Exclusion is a real issue when new technologies arise.

One example of the challenge of access and inclusion from the second industrial revolution is the electrification of cities and households. More than a century later, in 2019, more than 1 billion people around the world still lack access to electricity infrastructure.[71]

This has not been an easy challenge to solve, and serious efforts exist to close this remaining gap. For example, over the Past few years, the Modi government in India set the ambitious goal of achieving full energy access to all households in the country.[72] Indeed, the Indian government declared victory in the electrification of the entire country in January 2019.[73] However, despite this success and the huge investment that characterized the push for rural electrification, recent research indicates that there remains significant disparity across states and rural areas: A study of 10,000 households and 2,000 enterprises by Smart Power India (SPI) and the Initiative for Sustainable Energy Policy (ISEP) found that while the share of connected rural enterprises is over 90% in Odisha and Rajasthan, it is lower than 60% in Uttar Pradesh and Bihar.[74]

The importance of internet access

A similar story pertains to internet access, one of the foundational technologies of the third industrial revolution. Just under half of the world's population still lacks access to the internet, despite 85% of the world living within 3G coverage areas. In many developing economies and regions, research shows that this shortfall has been caused by: insufficient information and communications technology infrastructure; inadequate affordability of internet service and digital devices; a deficit of digital skills, awareness and cultural acceptance; and limited availability of locally relevant digital content, especially material in local languages or content that targets users in specific regions.[75]

Given that the technologies of the Fourth Industrial Revolution take access to the digital networks and capabilities of the third industrial revolution for granted, ensuring universal access to the internet is essential. Without it, portions of the global population could lose out on burgeoning opportunities, increasing future disparities.

Focusing on the marginal user

A common driver behind the way that groups are excluded from the rollout of new technologies is rooted in economics. The commercialization of technology requires an addressable market of sufficient size, and it is both rational and inevitable that technologies will therefore be optimized for, and served to, members of that market, where it exists.

As in the case of rural access to both electricity infrastructure and the internet, households or individuals that diverge sufficiently from the "central user" for a technology will remain underserved – because building infrastructure that reaches

them is uneconomic, because they lack the economic ability to pay for services, or because the form or substance of the content simply does not pertain to them.

Yet protecting and serving the "marginal user" is exactly the role of government in setting regulation, public policy and governing infrastructure. Public (and privatized) postal services must therefore serve even the most remote permanent residents of a country, and access to water and power are, in many countries, a legal right for residents.

Indeed, in 2017, the UK's Department for Digital, Culture, Media & Sport announced that universal high-speed broadband will be delivered by a regulatory Universal Service Obligation (USO), giving everyone in the UK access to speeds of at least 10 Mbps by 2020.[76]

2.2.4 Driving increased employment and skills development

As emerging technologies introduce new ways to create value and disrupt current industries and organizational models, labour markets are put under pressure.

There are signs that the net effect of such shifts are positive: According to the World Economic Forum's Future of Jobs Report 2018, while 75 million jobs are expected to be displaced in the next five years, another 133 million are expected to be created across 20 developed and emerging economies. However, while net effects may be positive, the timing and extent of large-scale displacement across multiple sectors will require a wholly new approach to job transitions.

Skills development for the Fourth Industrial Revolution

Based on previous technological and economic transitions, shifting skills within the same job will be a more common and important driver of change than the creation and destruction of entire job categories, requiring widespread worker retraining and adjustment. World Economic Forum research suggests that more than half of all employees will require reskilling (and "upskilling") by 2022. The investment associated with such reskilling is significant: The Forum estimates that over a third will require more than six months of additional training.

Businesses are not set up for the scale and time commitment of this type of skills investment. Only around 30% of employees in the jobs most exposed to technological disruption report receiving any kind of training in the past year, and most companies say they intend to target retraining programmes at high-performing employees.[77] This implies that the employees most at risk of job or skill disruption are also far less likely to be provided with retraining to cope, potentially increasing inequality.

If national and global actors, including multinationals as well as the education sector and policy-makers, fail to support workers attaining and upgrading skills, the outcome could be a true "lose-lose" scenario – rapid technological change accompanied by talent shortages, mass unemployment and growing inequality.

This can be offset by public governance. As the International Labour Organization (ILO) has stated, countries have the opportunity to shift away from underinvestment in training and education and build a universal framework to support lifelong learning, including stronger and better-financed active labour market training and adjustment policies, as well as expanded public employment services and a social protection floor.[78] It also suggests changing the accounting treatment by businesses of training expenses so that, like capital investments, they are charged against earnings over several years.

Managing the changing world of independent work

Emerging technologies are also driving new opportunities for direct job creation and more flexible modes of work. As production techniques, technology and business models evolve and take advantage of a digitally connected labour market, systems are emerging that draw on diverse pools of talent and specialized skills from around the world.

Today, 20–30% of the working-age population in the United States and the EU-15 engage in some form of independent work. This number is expected to grow[79] as digital platforms create new opportunities for more independent and on-demand work, and as individuals find new, more direct ways to tap into demand from customers.

This shift towards independent work presents a range of challenges and uncertainties for workers, such as wage and employment insecurity and reduced access to social protection. For governments and the private sector to make the most of these growing opportunities while ensuring that worker rights are fully protected, greater collaboration is needed to reform and create institutions and enabling environments. This will maximize flexible, high-quality job creation while supporting workers with talent development, career transitions and access to suitable social insurance and safety nets.

What does this look like in practice? One model is the call by the ILO Global Commission for a Universal Labour Guarantee in which all workers, regardless of their contractual arrangement or employment status, should enjoy fundamental workers' rights, an "adequate living wage", maximum limits on working hours and the protection of safety and health at work. The collective representation

of workers and employers through social dialogue should be ensured as a public good and actively promoted through public policies. And from parental leave to investment in public care services, policies need to encourage the sharing of unpaid care work in the home to create genuine equality of opportunity in the workplace. Strengthening women's voices and leadership, eliminating violence and harassment at work and implementing pay transparency policies are also preconditions for gender equality.

Investing in public goods to support employment growth

Managing the impact of technological transitions also means investing where existing economic activity and employment have positive externalities. Here, the public and private sectors need to collaborate to accelerate investment in those labour-intensive sectors that are poised for growth and have positive externalities for society, including sustainable water, energy, digital and transport infrastructure, the care economy, education and training and the rural economy. The Business Commission for Sustainable Development has estimated that achieving the Sustainable Development Goals would open $12 trillion of market opportunities in four economic systems alone – food and agriculture, cities, energy and materials, and health and well-being – as well as create 380 million jobs by 2030.[80] Capitalizing more effectively on these employment expansion opportunities can help countries compensate for the labour-displacing and potentially demand-suppressing effects of automation and economic integration.

2.2.5 Governing emerging technologies for sustainability

A final cross-cutting theme for the governance of emerging technologies is their impact on the environment and prospects for sustainable development. Unfortunately, the concept of environmental impact has not been considered the highest-priority issue when designing and disseminating emerging technologies. Negative externalities are rarely included in the price of technology, as linear economic and material thinking dominates over "the circular economy", and the total societal costs of products are overlooked.

The consequence of such a neglect of environmental considerations in the previous three industrial revolutions has led to what is arguably one of humanity's largest challenges today: climate change and unprecedented loss of biodiversity.

Anthropogenic climate change has led to greenhouse gases in 2019 being at their highest levels in 3 million years. The chemistry of the oceans is changing faster than at any point in perhaps 300 million years because of the annual absorption of approximately 33% of greenhouse gases. The resulting acidification and rising temperatures of the ocean is having an unprecedented impact on corals and fish stocks.

The Earth is rapidly losing its biodiversity at mass-extinction rates, such that 70% of its genetic biodiversity has become extinct. Meanwhile, deforestation rates in the Amazon Basin could lead to an 8% drop in regional rainfall by 2050, triggering a shift to a "savannah state" for many regions, with wider consequences for the Earth's atmospheric circulatory systems. Polar and glacial ice fields are retreating at an alarming rate with potentially calamitous knock-on effects for the wider water and climate systems. The Arctic is now the fastest-warming region on the planet and the resultant warmer air and water at the North Pole is disturbing the predictability of the Gulf and the jet streams that help to regulate the Earth's climatic circulatory system.[81]

Addressing these climate emergencies and bringing emerging technologies in line with the UN's Sustainable Development Goals (SDGs) is a collective goal. Accordingly, there are four cross-cutting aspects of emerging technology governance that relate to the environment:

Spurring the development of more sustainable technologies to improve efficiency

Some emerging technologies promise to be more efficient alternatives or complements for a range of existing systems that create negative environmental externalities. The hope is that emerging technologies represent cleaner, more sustainable ways of achieving the same goals.

One example of this is the role that electric vehicles might play in supporting efforts to switch countries to renewable energy. Because electric vehicles contain batteries that, when charging, are primarily connected to the national grid, they represent an energy storage resource that allows a greater reliance on renewable yet intermittent electricity sources such as solar or wind power.[82]

Another example is the opportunities for machine learning systems, in combination with smart sensors and connected traffic lights, to reduce commuting times and therefore vehicle emissions in crowded cities. The city of Hangzhou has used cloud-based machine learning systems provided by Alibaba to reduce traffic jams by 15%.[83] In Kuala Lumpur, current internal estimates by Alibaba indicate that its City Brain programme has helped the average commuter reduce their time on the road by 20 minutes – a huge saving across the city.[84]

Governance of emerging technologies in this way could be achieved by setting performance and efficiency requirements or targets for a broad array of systems where emissions or other environmental impacts are already a challenge. A second governance challenge will be the "rebound" effect, whereby efficiency gains are lost due to changed behaviour. This may require interventions in pricing, to ensure that a price decrease driven by more efficient material use does not simply result in greater consumption.

Monitoring the natural, built and cultivated environments

A second governance issue for emerging technologies is related to whether and how they are used to monitor environmental resources, land use and extraction processes.

For example, it is possible to use satellite imagery combined with machine learning to assess agricultural yields,[85] detect illegal mining and forestry,[86] monitor water resources[87] and measure the sprawl of cities[88] – all from space.

Both public and private efforts are required to make such methods readily available, particularly to communities in the Global South. One such example is Digital Earth Africa, which uses an open-source codebase developed by the Government of Australia to enable stakeholders across Africa to track environmental and land-use changes across the continent in unprecedented detail through satellite data. This will provide valuable insights for better decision-making across many areas, including flooding, droughts, soil and coastal erosion, agriculture, forest cover, land-use and land-cover changes, water availability and quality, and changes to human settlements.[89]

Limiting the externalities of new technologies

Emerging technologies can and do have significant environmental impacts. One of the most powerful pathways for negative externalities of emerging technologies is linked to their energy cost during use.

A recent study on the training of natural language processing (NLP) machine learning algorithms calculated that emissions for training a model with neural architecture were comparable to as much as four lifetimes' worth of emissions from the average car.[90] Likewise, mining cryptocurrencies such as bitcoin, Ethereum or Monero on various forms of blockchain technologies currently require more energy than mining copper, gold or platinum for equal amounts of value.[91] Bitcoin mining used an estimated 30 terawatt hours of electricity in 2017 – equivalent to the amount required to power the entire nation of Ireland for a year.[92]

Some emerging technologies may reduce the efficiency of energy use while delivering added convenience, either directly or indirectly. For example, wireless charging, a method of charging batteries that it is estimated will be used for charging approximately 90% of smartphones by 2030,[93] is at most only 80% efficient when compared to wired recharging. In January 2019, Hyundai and Kia launched a wireless charging system for autonomous vehicles[94] – widespread adoption of this system would result in a significant increase in energy demand for autonomous electric vehicles, accompanied by the equivalent emissions.

Another externality of emerging technologies comes from poor life-cycle management of the materials required for their manufacture and operation. For example, many breakthrough technologies – such as drones, autonomous vehicles and IoT sensors – rely on batteries. Raw material and manufacturing processes exact a significant environmental toll, thanks to pollution and wastage in creating the batteries themselves. Then, at the end of life, 11 million tonnes of spent lithium-ion batteries are forecast to be discarded by 2030. Today, relatively few systems are in place to enable reuse and recycling.[95]

Governance to reduce the direct and indirect impacts of emerging technologies will require broad, multistakeholder efforts. An example of this is the Global Battery Alliance, a global collaboration platform that hopes to inspire and accelerate action towards socially responsible, environmentally sustainable and innovative battery value chains to power the emerging technologies at the heart of the Fourth Industrial Revolution.[96] In addition, efficiency requirements for emerging technologies themselves – as well as the data centres they often rely on – could be considered.

Technologies directed at changing the environment

A final issue related to emerging technologies concerns efforts to deploy tech in ways that directly alter the environment or climate.

One such example is the use of gene drives, which are efforts to change and manage the characteristics of an entire species through germline editing. These are already being trialled in attempts to wipe out malaria.[97] With CRISPR, such strategies could become more common, especially with

invasive species, but there are serious drawbacks that need to be addressed.[98] Another set of examples are proposals around geoengineering, which are large-scale, deliberate interventions in the Earth's natural systems. By deploying chemicals in the upper atmosphere, releasing engineered microbes into marshland or using space-born objects, geoengineering could shift rainfall patterns, create artificial sources of sunshine and alter the biospheres.[99]

Both gene drives and geoengineering efforts represent exciting ways to tackle existing challenges – but they also represent interventions in the natural world that are potentially irreversible, making their governance particularly critical.

Given these aspects, technology governance efforts related to the environment could focus on three cross-cutting goals.

First, creating performance requirements and sustainability targets for both the development and deployment of emerging technologies themselves, and their use to support existing activities that contribute to climate change, biodiversity loss or pollution.

Second, deploying emerging technologies to help govern the environmental global commons. These include monitoring greenhouse gases, tracking biodiversity loss and related treaty-based commitments, and the sustainable management and demand in supply and value chains through better traceability. This will require that emerging technologies are deployed as "global public goods" in support of the sustainable development goals and local conservation efforts.

And third, ensuring that all relevant stakeholders are engaged in collaborative efforts towards the sustainable use of emerging technologies to avoid the environmental damage created during prior industrial revolutions.

Part 3: Addressing barriers and making progress

As the frameworks and analysis above indicate, governing emerging technology requires collective action, undertaken in a myriad of networked modes. The boundary-crossing nature of emerging technologies require collaborative policy-making architectures that can both adapt to the speed of technological change and address the variety of issues that pop up when new technologies emerge from our shared digital infrastructure.[100]

The history of collective action demonstrates that building such an architecture and developing shareable, scalable governance approaches requires cultivating trust and a cooperative spirit among diverse stakeholder groups.

As the World Economic Forum has argued previously, the goal is to develop shared architecture and policy frameworks that amount to an "operating system upgrade" for the Fourth Industrial Revolution.

So, what is preventing private companies and civil society from solving these issues?

3.1 The challenge of collective action

The benefits of many emerging technologies extend beyond the sum of their inputs. At scale, they create otherwise inaccessible opportunities for furthering scientific discovery, medical applications and economic innovation. For example, platforms for data-model sharing in medicine can help doctors find and use models that are not accessible in their local networks, while simultaneously aligning data and standardizing data management.[101]

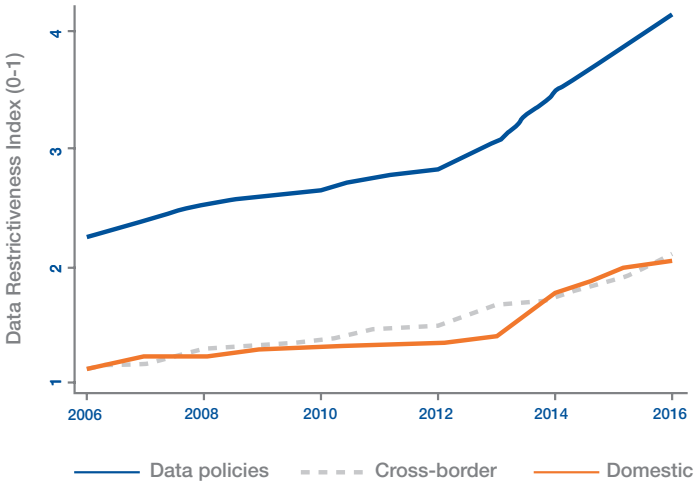
Emerging technologies are also catalysts and mitigators of externalities, both positive and negative, and their impact very much depends on the processes and policies we set for integrating them into our economic, political and social systems. All of this requires expensive, time-consuming cooperation among parties with different interests, languages and time horizons.

Global policy development for emerging technologies is therefore a crucial collective problem. Most actors at the individual, organizational and national levels would benefit from externalities of scale, such as network effects that can be achieved only through the wide diffusion of technologies. As these technologies span political and natural boundaries, however, questions arise as to which methodologies, standards and regulations apply. This challenge is difficult to gauge due to a number of variables, including how well the technology is understood, how it restructures power dynamics, where the investment lies, who reaps the benefits, who loses out, what social impact it will have and more.

Collective-action problems cannot be tackled or solved by one group, industry or nation alone. Shared digital infrastructure and emerging technologies come with a variety of issues that require cooperation in order to be solved, such as cross-border data flows, fast-scaling propaganda and misinformation, secure network development and decentralized network management. Without a robust architecture for global governance to address these, credibility, security, mutual trade benefits and investment potential are all jeopardized.

In the Fourth Industrial Revolution, cross-border data flow is arguably one of the most important issues, presenting many challenges. According to the OECD, digital protectionism has risen steadily since 2006, with a sharp uptick since 2013, limiting the potential of the global economy.[102] Data-sharing comes with benefits and risks, though in this "prisoners dilemma", many nations seem to be defecting in favour of controlling the infrastructure and the data, thus lowering the overall economic output.[103]

Figure 3.3 from the Regulatory and IRC report, OECD, 2019



In June of this year, in response to this protectionist trend, the United Nations High-Level Panel (UNHLP) on Digital Cooperation proposed a "digital commons architecture" that would support collaboration and help drive solutions that meet the SDGs while simultaneously addressing the potential for social harm of emerging technologies and their potential for dual-use.[104]

Authority and enforcement of agreements requires cooperation and the cultivation of trust among state actors. Without collaborative architecture for nations, municipalities, industries and experts to be able to come together to help shape policy, the ability to prosper is limited, and the probability of detrimental outcomes expanded.

Another collective concern is that not everyone has the vantage point from which to see or understand the way technologies are shifting the foundations of industry, society and global politics.

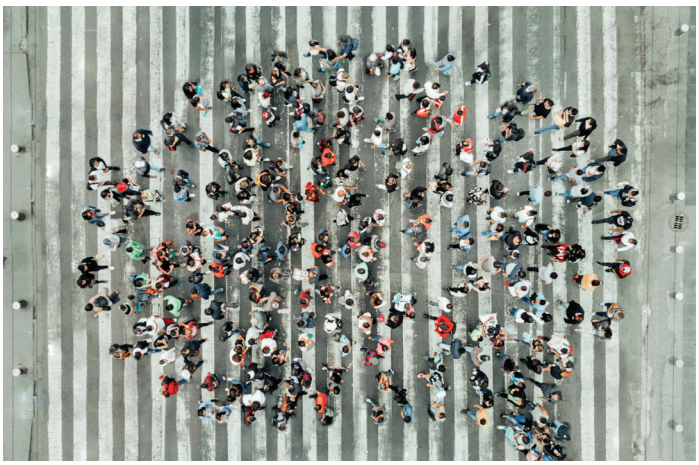
While global challenges make headlines and tech-savvy leaders are aware that the rapid development and scaling

of technologies is having an impact on the foundations of society, business and politics, work with government representatives from across the globe has shown that many tasks facing emerging economies are more closely focused on pressing immediate tasks concerning physical security, mobility and access.[105] This lag, known as the pacing problem,[106] often means there is little time left to consider the emerging technological threats on the horizon, especially those that seem relatively limited or related to social issues outside the normal bounds of consideration.

There is a danger, however, that if countries are unable to come together to work collectively on these issues, this could recreate problematic relationships of dependency, leaving some countries open to exploitation by technology leaders and investment requirements. Moreover, without shared policy-making and open collaboration, we risk reinventing the wheel time and again, whereas existing scalable and transferable policies could be better suited.

Another major challenge is cultivating awareness of the tools and frameworks that are currently available, such as policy development toolkits, academic approaches on ethical product development, strategies for working with regulators and responsible innovation. Knowledge of previous examples of successful policies from industry, cross-sector, municipal, national and/or international levels is often quite low, since many stakeholder groups have limited access to one another.

Making successful policies in other municipalities, countries or industries visible to those who are looking for examples from which to build is an important way to help. Not all regulators have the resources, time or capabilities to draw from external sources, nor are they all of similar scope and nature. Many governance schemes rely on the creation of ad hoc and completely new responses to issues that have already been addressed elsewhere.



3.2 Surmounting impediments to action

Discussions among the members of the Forum's Fourth Industrial Revolution Global Councils and other governance experts imply that there are a range of impediments to moving forward and resolving many of the collective-action challenges discussed above. These impediments come in a variety of shapes and sizes, though they primarily fall into three categories: barriers, gaps and divergent interests.

Overcoming barriers

Barriers are obstructions and can be structural, technical or social. Examples include jurisdictional conflicts such as regional or national data policies, technical interoperability hurdles that affect platforms, migration policies that affect the flow of talent, or social/cultural stances that have a significant impact on politics, such as many European nations' influential perspectives on genetically modified organisms.

While some policy-making barriers have been constructed with the purpose of maintaining divisions, others have developed naturally out of the types of governance processes that have been productive and useful to nations over the past half-century or more.

Barriers have, historically, established authority, framed accountability and represented normative divisions between communities, both at local and national scales. They are useful when it comes to setting parameters, but in a world where the convergence of technologies is producing surprising benefits and risks, they can deter, complicate and impede our collaborative capabilities, especially when it comes to how we create, share and scale governance approaches.

Cost is one of the most important barriers. While the marginal cost of digital products and services can be almost zero, the cost of building new digital infrastructure – such as 5G networks – is very high. It doesn't make financial sense to develop competing networks.[107] Rather, the infrastructure serves more people when costs and expertise are shared. However, sharing the cost of new network infrastructure implies other costs – particularly coordination costs required to come to agreement with other operators.

The same rule applies to governance. The business case for new governance approaches requires that rules benefit multiple stakeholders. Yet, above and beyond the effort required to review existing or craft new regulations or standards, there is additional cost to creating governance models that truly take dynamic, often competing, multistakeholder needs into account. In this way, both the perceived and real cost of aligning policies can act as a barrier to action.

Other barriers are social. Technologies are affecting everyday lives – social relationships, jobs and opportunities. Recent political fragmentation in many nations has been connected to rising inequality that is in part due to technology. For example, sociologists have identified technology – computerization of the workplace that favours high skill levels – as one of the primary causes (responsible for one quarter) of rising wage inequality in the United States.[108] Inequality drives barriers between social groups, affecting political cohesion. In addition, cultural differences can extend from fundamentally different ways of looking at the world, different collective goals and varying priorities. These factors can result in significantly different policies that conflict when extended beyond sovereign borders.

Bridging gaps

The second type of impediment is a gap – a space without established rules, an area lacking important capacities, or a common zone without clear frameworks for cooperation.

Examples of gaps include technical skills gaps in emerging economies that hinder policy development in a range of areas, a lack of standards for liability regarding outcomes of machine learning systems, or an absence of agreed authority mechanisms for decentralized networks such as those underpinning some cryptocurrencies.

The inability of many institutions to speak each other's languages and the lack of deliberative space on policy frameworks and global governance are two common gaps highlighted by policy-makers and regulatory experts. There are too few interdisciplinary forums where decision-makers can share skills, exchange practices and generate new ideas about cooperative and innovative approaches to technological governance.

There is also a trust gap among governments when dealing with digital technologies and cyberspace.[109] Governments are reluctant to ratify agreements if they don't have full vision of the issues, are unsure about control over the regulatory outcomes and/or are unclear about enforcement mechanisms. Geopolitical issues also cloud the issue as it has become clear that technology providers closely aligned with the state have more control over the networks and the resulting data. Shared infrastructure, and the need for high levels of interoperability, means that areas of mutual benefit also present increased surfaces of vulnerability for malevolent actors. Cybersecurity risks are political concerns,[110] and demanding new ways of thinking about risk assessment, national assets and the rules of engagement.

A third set of gaps relates to expertise. The complexity of emerging technologies and their reliance on digital skill sets has created an expertise gap in almost all countries – advanced, emerging and developing alike – when it comes to policy leaders deeply understanding the attributes and potential impact of these technologies. This is exacerbated by the fact that many political systems have not previously had a need for government officials to be deeply knowledgeable about technologies to be able to make socially and economically relevant decisions. Today, however, this lack of understanding can hinder policy development, and it requires better communication between businesses, technical experts and policy-makers in order to develop successful governance protocols.[111]

This last gap points to the natural barriers and isolating behaviour that takes place between businesses and regulatory institutions. Just as governments may lack technical knowledge, there is also a need for entrepreneurs to understand how governance processes work and which regulations may be relevant to them – especially since many technologies, as previously mentioned, blur disciplinary and industry boundaries as well as legislative barriers.

Policy gaps are also appearing as technologies affect traditional value chains. For instance, the effects of machine learning on material science and bioengineering, innovations in multidimensional printing, and the enabling networks and software for drones and autonomous vehicles have required innovative business models that do not conform to a system of policies built for a world of traditional manufacturing.[112]

Aligning divergent interests

The third type of impediment stakeholders face is the existence of divergent interests. Goals, visions and desired outcomes are often closely linked with our incentives and, in areas of competition and resource scarcity, it can be difficult to align with other parties, even if the ultimate outcome would be better for both. An example of such divergent interests manifesting in the public sphere is the threat of protectionist data policies, where each state would prefer to have control over the sources and use of data relating to its citizens.[113]

Governments also have interests in maintaining sovereignty, while individuals and businesses may be more willing to adapt to the more amenable environments for their needs. For example, the decentralized character of blockchain provides useful capabilities to individuals, such as smart contract execution, and it provides both anonymity and transparency of record. Nevertheless, decentralization also creates governance challenges, especially when it comes to conflict resolution and jurisdictional claims.

Business interests have often been perceived to be at odds with those of society. Corporate social responsibility (CSR) commitments and environmental, social and governance (ESG) reporting help to ameliorate those concerns. Conflicts can also emerge between the business model of companies and those of national governments and regional groupings. A much-discussed example can be seen in the interplay between platforms that rely heavily on advertising and therefore make multiple uses of consumer data on the one hand, and policy-makers searching for ways to protect and secure citizen data on the other hand. Furthermore, there are diverging cultural and societal norms that affect how communities regard issues such as security and privacy.

Finally, conflicts arise as markets use information and run afoul of the interests of individuals who will be affected by greater transparency. For example, a company's attempt to collect air-quality data through connected devices could be problematic for lower-income residents if their neighbourhoods were shown to have poor air quality. Such transparency could, via market forces, feed a vicious cycle that penalizes those in impoverished areas, causing further financial harm should negative data devalue their property.

Part 4: How stakeholders can lead technology governance

The multistakeholder and multidimensional nature of the challenges outlined above puts the responsibility of action on stakeholders from all sectors and jurisdictions. Working together, they will need to tackle the cross-cutting challenges as well as the technical and scientific challenges in order to develop constructive and manageable policies.

4.1 What governments should do

Government, the aggregate of institutions that traditionally hold the responsibilities of managing technological outcomes and societal needs, is struggling to keep up with the rapid changes in the emerging technology landscape. While this may not be a new phenomenon, here below are five guidelines for governments to strengthen technology policy in the Fourth Industrial Revolution:

Adopt an agile digital mindset
For governments to secure effective technology policy in the Fourth Industrial Revolution, they must rethink standard regulatory approaches by embracing new and agile solutions for governing technology, building technology skills resources, cultivating evidence-based practices, learning from failures, and viewing technology policy as a continuously evolving process. Adopting a digital mindset also involves the use of digital solutions as an opportunity for more responsive governance, and employing digital solutions can enable more targeted policy-making as, for example, is already done in fintech through regulatory technology. Above all, they need to ensure the citizen is always put first, so that policy frameworks continue to be inclusive and sustainable.

Invest in digital skills and digital leadership inside the government
To understand and keep pace with technological developments, governments need to invest sufficient resources in digital skills within government entities. Successful models for strengthening digital leadership include appointing technology ambassadors, chief digital officers or chief innovation officers. In these positions, policy-makers are recruited with specific mandates to follow technology innovation and design technology policy across different government departments. Those digital leaders can successfully steer government departments, increasing skills through on-the-job training followed by mentoring. Other models include creating secondments and internship opportunities in government. Recruiting industry leaders to serve as change agents by working within government – for example, the USA's Presidential Innovation Fellows – is one possibility. Another is deploying government employees to spend time in industry or international policy-making organizations by way of cross-collaboration.

Create a climate for technology policy experimentation
When we are unsure about the potential of technology and how to regulate it, policy-makers find it hard to implement new rules at scale. There are, however, tools that can be used to enable innovative responses at the local/municipal level. Policy labs and regulatory sandboxes are becoming important tools in creating innovative technology policy, applying the principles of scientific labs and product design – experiment, testing and measurement – to technology innovation. This creates a parallel universe, where policy-makers interact more freely with businesses and citizens to co-design human-centred technology policy that can later be scaled.

Open government to new stakeholders
The technology revolution comes with a lot of promises, but also with a lot of real and perceived risks, such as loss of trust and increasing inequality. Technology policy solutions require multistakeholder input to address their broader impacts, and this has been historically lacking. To build trust, governments need to engage with citizens and corporations to understand

and co-design solutions that are human-centred and inclusive. Technology itself can be an enabler of such processes by providing open data and open government and by using crowdsourcing techniques to seek input from citizens and corporations in policy-making processes.

Think – and collaborate – internationally
As data flows across borders and technology companies act globally, governments need to think of technology governance across borders as well. In this context, there is broad agreement that improved cooperation is needed, as reflected by the UN High Level Panel on Digital Cooperation's tech report,[114] which also shares a number of interesting examples of international cooperation. Furthermore, such cooperation will need to take multiple diverse forms, and governments, the private sector and civil society will need to find new ways to work together to steer an effective path between extremes of overregulation and complete laissez-faire.

4.2 What industry should do

Industry players, as one of the primary holders of critical technological expertise, have an unprecedented opportunity to partner with government and civil-society stakeholders to produce policies and practices that result in mutual benefit. Championing inclusive and sustainable approaches to technological development along with matching policy priorities can be beneficial to companies by building their reputational capital with customers and consumers, all the while signalling to regulators their ability to adapt and respond to the dynamic transformation of the Fourth Industrial Revolution. Fundamental steps that companies can take are:

Develop a clear IT governance framework for the company
All firms now deal in digital resources. Having clear policies about information management within the company increases the value that firms can derive from digital resources. Responsible policies for data management ensure a level of control necessary for both legal compliance issues as well as establishing a culture of practice that is critical for ethics purposes as the landscape evolves. A solid foundation in this area pays dividends across the board. IT governance is now a basic requirement in an ever-more connected enterprise environment. It should also include tasks beyond taking care of hardware or managing data security. It should be expansive enough to ensure that the company's board is sufficiently digitally savvy and that the chief information officer's role is clear vis-a-vis business unit heads so that proper protocols and processes are sufficiently propagated throughout the company.

Establish clear ethical frameworks and compliance mechanisms
Ethics is easier to adopt than many businesses assume. The freedom to have conversations about the ethical use of data or ethical responses to challenging scenarios can be normalized in a work environment. The main issue here is to distinguish ethical compliance from legal compliance. Many firms are adopting codes of ethics and, in doing so, are beginning to create an ethical consensus around the types of responsible behaviour that are expected beyond just technically following the rules.

Building on proper data and information management frameworks, a focus on subsequent ethical compliance issues is an additional buttress against reputational and financial risk. Useful models of ethical compliance are emerging, such as third-party auditing, counterfactual AI, and ethics value models (the other EVMs). Chief executive officers can consider creating an agenda around tech responsibility within their companies that can be added to internal ESG reporting. Several models for such a framework are under development, such as GSMA's Digital Declaration.[115]

Deploy technologies to help solve governance challenges
Pilot programmes and sandboxes are two methods of experimenting with new technologies to monitor and manage outcomes, as well as making sure potential negative externalities are limited. These same methods can be employed by firms in ways that address the cross-cutting challenges listed in section 2.2. For example, secure multiparty computation allows the training of an AI on many datasets held by different actors in multiple jurisdictions without the need to share potentially sensitive data. If successfully deployed, such technologies can help mitigate vulnerabilities associated with interoperability and concerns about personally identifiable data.

Blockchain and other distributed ledger technologies can also be of service when both transparency and anonymity may be needed. This is especially the case in areas where parties need to rely on each other, both need access to transactional data, and/or the data needs to be visible to multiple parties or the public.[116]

Technologies can also be deployed to encourage inclusion from stakeholders in both the public and private realms. This is especially helpful in areas such as product development where individual, company and industry interests must consider a wider set of social and cultural interests. Using technologies to collaborate with stakeholders can save time in development and anticipate deployment hiccups and areas of societal resistance, ultimately reinforcing more robust decision-making practices.

4.3 What civil society should do

Building collaborative architectures in technological innovation has always required civil society organizations to play a variety of cross-cutting roles for the common good, even as the sector faces a range of internal barriers and significant challenges from other sectors (including a lack of resources, shrinking civic space, difficult legislative and operational environments etc.). As is often the case, marginalized populations bear the greatest costs associated with technological development, as evidenced by numerous examples from past industrial revolutions. The negative impacts of industrialization led to the rise of organized, citizen-based activism and civil societies advocating for improved conditions for workers, marginalized communities of ethnic, socioeconomic and sexual minorities, and others when the progress of industry and government during those industrial revolutions failed to trickle down.

Civil society – including humanitarian, development, advocacy, philanthropy, civic tech, social entrepreneurs

and community-based organizations – has long-standing experience in both innovating and collaborating under pressure, for example: scoping and evaluating the complexity of harms related to society's most marginalized populations; championing accountability and feedback mechanisms in large-scale societal change; and adopting new approaches to working with other sectors to ensure new technological innovations do not deepen greater inequalities.

As a broader set of stakeholders understand and weigh the consequences of deploying technologies in already unequal societies, civil society can provide three critical functions in building collaborative architectures in technology governance.

Promote human rights as a fundamental aspect of a digital world

Civil society's promotion of human rights – rather than ethics – as a basis for defining responsible governance puts the issue within the jurisdiction of multistakeholder human rights frameworks and their associated monitoring mechanisms and communities. Extending beyond a corporate understandings of "ethics", rights enable cross-sector evaluation across different legal jurisdictions and value systems and, when grounding multistakeholder discussions on AI, help avoid "ethics washing" – especially where the adoption of principles and establishment of ethical review boards can be vague enough to avoid meaningful enforcement.

In this respect, within collaborative architectures in technology governance, a wide variety of civil-society actors can contribute as follows:

1. As advocates: raising awareness of societal issues and challenges, and advocating for fairness and trust (e.g. Indian civil-society campaigning on zero-rated services, Australian activism on healthcare data and consent, Toronto's declaration on rights to equality and non-discrimination in machine learning)
2. As watchdogs: holding institutions, organizations and individuals to account, promoting transparency and accountability (e.g. ProPublica's investigation of predictive analytics for crime prevention; ThingsCon's Trustable Technology Mark initiative etc.)
3. As domain experts: applying rights-based approaches to technology governance (e.g. WeRobotics, Data and Society, UN Office of the High Commissioner for Human Rights, International Committee of the Red Cross etc.)

Share and co-create inclusive and participatory approaches to technology governance

In relation to the governance of digital and emerging technologies, the range of organizations in civil society bring long-term domain expertise, community networks, earned reputation and inclusive approaches that are critical to the human application of technology as they take into account experiences of identity, power and historic oppression that are not often part of governance conversations. This is particularly essential as public and commercial entities explore the use of emerging technologies such as AI and blockchain in areas such as criminal justice, digital identity, immigration and humanitarian response. More diverse voices need to be present to inform on the edge cases and how best to minimize trade-offs – as the current gender, racial and socioeconomic dynamics and perspectives of technology companies and other stakeholders are often implicitly biased towards Western, maleoriented experiences.

In this respect, within collaborative architectures in technology governance, civil society can act:

1. As innovators in process design: providing frameworks and resources in building inclusive approaches in technology design (e.g. the Engine Room, MERL Tech, World Wide Web Foundation, West Africa Civil Society Institute, Centre for Humanitarian Data etc.)
2. As innovators in governance design: exploring new forms of institutions in response to challenges in legal environments with limited data protections (e.g. Open Data Institute's data trusts, Open Algorithms Project etc.)
3. As definers of standards: employing existing protocols and multistakeholder mechanisms for changes in practice (e.g. International Governance Forum, Institute of Electrical and Electronics Engineering, the World Economic Forum etc.)

Create models for translation across sectors, disciplines and experiences on technology and society issues

While several new cross-sector initiatives and convenings have emerged on technology and society issues, these groups are often housed within specific disciplines, with few stakeholders able to translate and bridge concepts across disciplines and regional experiences. Civil society can play a much-needed translation and communications role in discussing the Fourth Industrial Revolution, particularly in ensuring that the concepts discussed stay grounded in a diversity of lived experiences and focus on solutions that do not avoid acknowledging fundamental issues related to power and structural inequality. In its initiative on Preparing Civil Society for the Fourth Industrial Revolution, the World Economic Forum is partnering with global, regional and local civil-society organizations to accelerate the future readiness of the sector, through knowledge-sharing, multistakeholder collaboration and investment aimed at enabling environments for thriving civil societies.
In this respect, within collaborative architectures in technology governance, civil society can act:

1. As representatives: giving power to unrepresented or marginalized voices (e.g. Black Girls Code, Lesbians Who Tech + Allies etc.)
2. As capacity builders: providing education, training and other capacity building (e.g. Access Now, WITNESS, Nesta etc.)
3. As solidarity supporters: promoting fundamental and universal values (e.g. the Workers Lab, UNI Global Union, International Trade Union Confederation)

While civil society cannot address the range of governance-related challenges on its own, the sector's history of successes and failures in the human application of technology in vulnerable contexts provides critical insights in designing inclusive processes and minimizing trade-offs in already unequal societies.

Conclusion

The World Economic Forum's Centre for the Fourth Industrial Revolution is dedicated to addressing these collective action issues by providing resources dedicated to co-designing policies, refining governance frameworks and minimizing the risks of advancing science and technology.

The Forum has extended its network through the establishment of global centres that work on these collective issues from within the perspective and frameworks of partner governments. In addition, the World Economic Forum's inaugural Global Technology Governance Summit will take place in 2020 in order to provide a space for deliberation among governments, businesses, civil-society leaders and experts in order to inspire action.

The ideal scenario would be to work together loosely but collaboratively in the spirit of cooperation to realize the goals of upgrading institutions, involving relevant stakeholders, and generating the benefits of scale mentioned previously. Likewise, helping companies build relationships with regulators, their customers and the societies that provide their talent, infrastructure and markets helps stakeholder groups work across boundaries and understand the value that each brings to the bigger picture.

To make progress, we will have to continue to build awareness across stakeholder groups – both in terms of the Fourth Industrial Revolution technologies' benefits as well as their potential harms. Ultimately, this will mean creating further space for deliberation and assessment of social perspectives and values at the community, organizational and regulatory levels.

Acknowledgements

Primary Authors

Nicholas Davis, former Head of Society and Innovation at the World Economic Forum, Professor of Practice, Thunderbird School of Global Management, Arizona State University

Thomas Philbeck, Head of Technology, Society and Policy, World Economic Forum

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Endnotes

1 http://www3.weforum.org/docs/WEF_Agile_Governance_Reimagining_Policy-making_4IR_report.pdf (link as of 6/10/19).

2 http://www3.weforum.org/docs/WEF_Globalization_4.0_Call_for_Engagement.pdf (link as of 6/10/19).

3 https://www.weforum.org/centre-for-the-fourth-industrial-revolution/global_councils (link as of 6/10/19).

4 In 2013, the World Economic Forum's Global Agenda Council on Values undertook a study to examine which values were commonly held across countries and stakeholder groups, and found that three ideas were universally accepted as requiring focus and protection: the dignity and equity of human beings – whatever their race, gender, background or beliefs; the importance of a common good that transcends individual interests; and the need for stewardship – in the sense of a concern for future generations.

5 For example, https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2719130 (link as of 6/10/19).

6 For example, https://www.nytimes.com/2018/10/17/opinion/brazil-election-fake-news-whatsapp.html (link as of 6/10/19).

7 For example, http://gendershades.org/ (link as of 6/10/19).

8 https://syncedreview.com/2018/03/15/global-survey-of-autonomous-vehicle-regulations/ (link as of 6/10/19).

9 https://medium.com/politics-ai/an-overview-of-national-ai-strategies-2a70ec6edfd (link as of 6/10/19).

10 For example, the UK Financial Conduct Authority's regulatory sandbox approach: https://www.fca.org.uk/firms/regulatory-sandbox/cohort-5 (link as of 6/10/19).

11 Baldwin, R., Cave, M. and Lodge, M. (2010), *Oxford Handbook on Regulation*, Oxford University Press.

12 Lyall C., Tait, J., eds (2007), *New Modes of Governance: Developing an Integrated Policy Approach to Science, Technology, Risk and the Environment*, London: Routledge, 2017, p. 3.

13 Bache, I. (2003), *Governing through Governance: Education Policy Control Under New Labour*, *Political Studies*, 51(2), pp. 300–314.

14 Metcalfe, J.S. (1994), *Evolutionary Economics and Technology Policy, The Economic Journal*: The Journal of the British Economic Association, 1994, 104(425), pp. 931–944.

15 Lundvall, B.-A. and Borras, S. (2005), *Science, Technology and Innovation Policy*. Chapter published in Fagerberg, J., Mowery, D.C. and Nelson, R.R., eds (2005), *Innovation Handbook*, Oxford: Oxford University Press, Chapter 22, pp. 599–631.

16 Isaac, G. (2002), *Agricultural Biotechnology and Transatlantic Trade: Regulatory Barriers to GM Crops*, CABI Publishing.

17 Wilson, J., Mann, C. and Otsuki, T. (2003), *Trade Facilitation and Economic Development: Measuring the Impact*, World Bank Policy Research Working Papers, March 2003.

18 One example of this is the rollout of 5G technology, where over 90% of operators see an increase in network sharing with efforts to bring 5G to areas where it doesn't make sense to have multiple networks. McKinsey (2019), *Cutting through the 5G Hype: Survey Shows Telcos' Nuanced Views*: https://www.mckinsey.com/industries/telecommunications/our-insights/cutting-through-the-5g-hype-survey-shows-telcos-nuanced-views (link as of 6/10/19).

19 For example, Carin, B. and Shorr, D. (2013),*The G20 as a Lever for Progress*: https://www.cigionline.org/publications/g20-lever-progress (link as of 6/10/19).

20 Büthe, T. (2010), *Private Regulation in the Global Economy: A (P)review*, *Business and Politics*, 28 October 2010, 12(3).

21 https://www.suasnews.com/2019/01/what-the-world-can-learn-from-rwandas-approach-to-drones/ (link as of 6/10/19),

22 Büthe, T. (2010), *Engineering Uncontestedness? The Origins and Institutional Development of the International Electrotechnical Commission (IEC)*, *Business and Politics*, 12(3).

23 Ibid.

24 Yu, E. (2019) *Singapore Releases Guidelines for Deployment of Autonomous Vehicles*, ZDNet.com, 31 January 2019: https://www.zdnet.com/article/singapore-releases-guidelines-for-deployment-of-autonomous-vehicles/ (link as of 6/10/19).

25 Lyall, C., Tait, J., eds (2007), *New Modes of Governance: Developing an Integrated Policy Approach to Science, Technology, Risk and the Environment*, London: Routledge, 2017, p. 10.

26 Ibid.

27 Marchant, G. and Stevens, Y. (2017), *Resilience: A New Tool in the Risk Governance Toolbox for Emerging Technologies*: https://lawreview.law.ucdavis.edu/issues/51/1/Symposium/51-1_Marchant_Stevens.pdf (link as of 6/10/19),

28 Litan, R. (1991), *The Safety and Innovation Effects of US Liability Law: The Evidence*, *The American Economic Review*, 81(2), pp. 59–64: http://www.jstor.org.ezproxy.lib.swin.edu.au/stable/2006826 (link as of 6/10/19).

29 Marchant and Stevens (2017). Op cit.

30 Ibid.

31 Börzel, T.A. and Heard-Lauréote, K. (2009), *Networks in EU Multi-level Governance: Concepts and Contributions*, *Journal of Public Policy*, 29(2), August 2009, pp. 135–151: https://doi.org/10.1017/S0143814X09001044 (link as of 6/10/19).

32 Tömmel, I. and Verdun, A. (2009), *Innovative Governance in the European Union: The Politics of Multilevel Policymaking*, Boulder, CO and London: Lynne Rienner.

33 For example, the types of bias listed in Google's Machine Learning Crash Course: https://developers.google.com/machine-learning/crash-course/fairness/types-of-bias (link as of 6/10/19),

34 Collingridge, D. (1980), *The Social Control of Technology*. London: Frances Pinter.

35 Callander, S. and Martin, G.J. (2016), *Dynamic Policy-Making with Decay, American Journal of Political Science*, 61(1), January 2017, pp. 50–67.

36 World Economic Forum (2018), *Agile Governance: Reimagining Policy-Making in the Fourth Industrial Revolution*: http://www3.weforum.org/docs/WEF_Agile_Governance_Reimagining_Policy-making_4IR_report.pdf (link as of 6/10/19).

37 For example, Forbes (2019), *China's Efforts to Control Their Technology Future and its Far Reaching Impact*: https://www.forbes.com/sites/timbajarin/2019/07/19/chinas-efforts-to-control-their-technology-future-and-its-far-reaching-impact/#9536840fa844 (link as of 6/10/19).

38 For an overview of the links between city-level governance, technology and the built environment, see Meijer, A. and Rodriguez Bolivar, M.P. (2016), *Governing the Smart City: A Review of the Literature on Smart Urban Governance*, *International Review of Administrative Sciences*, 82(2), pp. 392–408.

39 Stokes, E. (2012), *Nanotechnology and the Products of Regulatory Inheritance*, *Journal of Law and Society*, 39(1), pp. 93–112.

40 Perkins, R. and Neumayer, E. (2012), *Does the "California Effect" Operate across Borders? Trading- and Investing-up in Automobile Emission Standards*, *Journal of European Public Policy*, 19(2), pp. 217–237, DOI: 10.1080/13501763.2011.609725.

41 https://www.iatp.org/documents/food-safety-and-gmos-new-nafta (link as of 6/10/19).

42 https://aipulse.org/soft-law-governance-of-artificial-intelligence/ (link as of 6/10/19).

43 CapitalOne July 2019 – 100 million-plus; Equifax 2017 – 140 million-plus; Marriott 2014–2018 – 300 million-plus: https://www.cnet.com/how-to/its-not-just-equifax-heres-every-major-security-breach-and-data-hack-so-far/ (link as of 6/10/19).

44 https://www.zdnet.com/article/51-tech-ceos-send-open-letter-to-congress-asking-for-a-federal-data-privacy-law/ (link as of 6/10/19).

45 World Economic Forum (2019*)*, *Data Collaboration for the Common Good*, April 2019: http://www3.weforum.org/docs/WEF_Data_Collaboration_for_the_Common_Good.pdf (link as of 6/10/19).

46 Ibid.

47 Manyika, J. et al. (2013), *Open Data: Unlocking Innovation and Performance with Liquid Information*, McKinsey Digital (October 2013): https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/open-data-unlocking-innovation-and-performance-with-liquid-information (link as of 6/10/19).

48 Information Accountability Foundation (2019), *Ethical Data Impact Assessments and Oversight Models*: http://informationaccountability.org/wp-content/uploads/Model-Ethical-Data-Impact-Assessment-January-2019-002.pdf (link as of 6/10/19).

49 Taddeo, M. and Bosco, F. (2019), *We Must Treat Cybersecurity Like a Public Good:* https://www.weforum.org/agenda/2019/08/we-must-treat-cybersecurity-like-public-good/ (link as of 6/10/19).

50 https://arstechnica.com/tech-policy/2019/04/yahoo-tries-to-settle-3-billion-account-data-breach-with-118-million-payout/ (link as of 6/10/19).

51 World Economic Forum (2019), *Data Collaboration for the Common Good*.

52 Privacy International (2019), "We Don't Want to Sell Our Data, We Want Data Rights!": https://privacyinternational.org/news-analysis/2683/we-dont-want-sell-our-data-we-want-data-rights (link as of 6/10/19).

53 Will.i.am, "We Need to Own Our Data as a Human Right – and Be Compensated for It", *The Economist*, 21 January 2019: https://www.economist.com/open-future/2019/01/21/we-need-to-own-our-data-as-a-human-right-and-be-compensated-for-it (link as of 6/10/19).

54 Apostle. J. (2018), *Lessons from Cambridge Analytica*: *One Way to Protect Your Data*, *Financial Times*, 20 March 2018: https://www.ft.com/content/43bc6d18-2b6f-11e8-97ec-4bd3494d5f14 (link as of 6/10/19).

55 The EU General Data Protection Regulation: https://ec.europa.eu/commission/priorities/justice-and-fundamental-rights/data-protection/2018-reform-eu-data-protection-rules_en (link as of 6/10/19).

56 http://www.privacy-regulation.eu/en/article-17-right-to-erasure-'right-to-be-forgotten'-GDPR.htm (link as of 6/10/19).

57 https://www.theguardian.com/business/2019/jul/10/gdpr-fines-ba-british-airways-marriott-data-watchdog (link as of 6/10/19).

58 DeMontjoye, Y.-A. (2014), *openPDS: Protecting the Privacy of Metadata through SafeAnswers*, 9 July, 2014: https://doi.org/10.1371/journal.pone.0098790 (link as of 6/10/19).

59 Sweeney, L. (2000), *Simple Demographics Often Identify People Uniquel*y, Carnegie Mellon University, Data Privacy Working Paper 3. Pittsburgh 2000: https://dataprivacylab.org/projects/identifiability/paper1.pdf (link as of 6/10/19).

60 World Economic Forum (2019), *Data Collaboration for the Common Good*.

61 https://www.hrw.org/news/2017/06/26/perils-back-door-encryption-mandates (link as of 6/10/19).

62 Barr, W.P. (2019), *Attorney General William P. Barr Delivers Keynote Address at the International Conference on Cyber Security*, 23 July 2019: https://www.justice.gov/opa/speech/attorney-general-william-p-barr-delivers-keynote-address-international-conference-cyber (link as of 6/10/19).

63 Government of Australia (2018), Telecommunications and Other Legislation Amendment (Assistance and Access) Bill 2018, 8 December 2018: https://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22legislation%2Fbillhome%2Fr6195%22 (link as of 6/10/19).

64 https://hackernoon.com/geography-of-bans-40abdfa066dd (link as of 6/10/19).

65 https://www.politico.com/story/2019/06/27/trump-officials-weigh-encryption-crackdown-1385306 (link as of 6/10/19).

66 For example, *The Guardian* (2018), *May Calls Again for Tech Firms to Act on Encrypted Messaging*: https://www.theguardian.com/technology/2018/jan/25/theresa-may-calls-tech-firms-act-encrypted-messaging (link as of 6/10/19).

67 For example, *Der Spiegel* (2019) *Seehofer will Messengerdienste zum Entschlüsseln Zwingen*,: https://www.spiegel.de/netzwelt/netzpolitik/horst-seehofer-will-messengerdienste-zum-entschluesseln-zwingen-a-1269121.html (link as of 6/10/19).

68 https://www.bleepingcomputer.com/news/security/german-minister-wants-secure-messengers-to-decrypt-chats/ (link as of 6/10/19).

69 European Commission (2017), *New European Interoperability Framework*, Luxembourg: Publications Office of the European Union, 2017: https://ec.europa.eu/isa2/sites/isa/files/eif_brochure_final.pdf (link as of 6/10/19).

70 Hoe, N.S. (2006), *Free/Open Source Software – Open Standards*, IDRC and Elsevier: http://hdl.handle.net/10625/50703 (link as of 6/10/19).

71 https://www.weforum.org/agenda/2018/06/1-billion-people-lack-electricity-solution-mini-grid-iea/ (link as of 6/10/19).

72 https://economictimes.indiatimes.com/industry/energy/power/with-1-million-homes-still-in-the-dark-modi-government-misses-power-goal/articleshow/67332253.cms?from=mdr (link as of 6/10/19).

73 https://www.powerforall.org/countries/india/universal-rural-electrification-india-not-so-fast (link as of 6/10/19).

74 https://www.rockefellerfoundation.org/report/rural-electrification-india-customer-behaviour-demand/ (link as of 6/10/19).

75 World Economic Forum (2016), *Internet for All: A Framework for Accelerating Internet Access and Adoption*: http://www3.weforum.org/docs/WEF_Internet_for_All_Framework_Accelerating_Internet_Access_Adoption_report_2016.pdf (link as of 6/10/19).

76 https://www.gov.uk/government/news/high-speed-broadband-to-become-a-legal-right (link as of 6/10/19).

77 World Economic Forum (2018), *Future of Jobs Report 2018:* http://www3.weforum.org/docs/WEF_Future_of_Jobs_2018.pdf (link as of 6/10/19).

78 International Labour Organization (2017), *World Social Protection Report 2017-19*: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_604882.pdf (link as of 6/10/19).

79 McKinsey Global Institute (2016), *Independent Work: Choice, Necessity and the Gig Economy*, October 2016.

80 The Business and Sustainable Development Commission (2017), *Better Business, Better World,* http://report.businesscommission.org/uploads/BetterBiz-BetterWorld_170215_012417.pdf (link as of 6/10/19),

81 World Economic Forum (2017), *Harnessing the Fourth Industrial Revolution for the Earth,* http://www3.weforum.org/docs/WEF_Harnessing_the_4IR_for_the_Earth.pdf (link as of 6/10/19).

82 https://www.theguardian.com/environment/2019/jul/11/electric-cars-could-form-battery-hubs-to-store-renewable-energy (link as of 6/10/19).

83 https://www.wired.co.uk/article/alibaba-city-brain-artificial-intelligence-china-kuala-lumpur (link as of 6/10/19).

84 Alibaba, personal communication.

85 Burke, M. and Lobell, D.B. (2017), *Satellite-Based Assessment of Yield Variation and Its Determinants in Smallholder African Systems*, *PNAS*, 15 February 2017: https://doi.org/10.1073/pnas.1616919114 (link as of 6/10/19).

86 Merugu, S. and Jain, K. (2013), *Change Detection and Estimation of Illegal Mining Using Satellite Images*, Proceedings of 2nd International Conference on Innovations in Electronics and Communication Engineering (ICIECE-2013), Hyderabad.

87 N. Mueller et al. (2016), *Water Observations from Space: Mapping Surface Water from 25 years of Landsat Imagery Across Australia*, Remote Sensing of Environment, Volume 174, March 2016, pp. 341-352: https://doi.org/10.1016/j.rse.2015.11.003 (link as of 6/10/19).

88 Sutton, P.C. (2003), *A Scale-Adjusted Measure of "Urban Sprawl" Using Night-Time Satellite Imagery*, *Remote Sensing of Environment*, 86(3), 15 August 2003, pp. 353-–69: https://doi.org/10.1016/S0034-4257(03)00078-6 (link as of 6/10/19).

89 https://www.digitalearthafrica.org/sites/default/files/2019-08/DE%20Africa%20fact%20sheet_0.pdf (link as of 6/10/19).

90 Strubell, E, Ganesh, A. and McCallum, A. (2019), *Energy and Policy Considerations for Deep Learning in NLP*, Proceedings of the 57th Annual Meeting of the Association for Computational Linguistics (ACL), Florence, Italy, July 2019.

91 Krause, M. and Tolaymat, R. (2018), *Quantification of Energy and Carbon costs for Mining Cryptocurrencies*, *Nature Sustainability*, 5 November 2018, pp. 711–718.

92 https://qz.com/1364657/bitcoins-energy-consumption-isnt-as-bad-as-you-think/ (link as of 6/10/19).

93 IEA (2019), *Electric Networks and Networks Annex, Global Forecast of Energy Use for Wireless Charging*, July 2019: https://www.iea-4e.org/publications (link as of 6/10/19).

94 https://electrek.co/2019/01/03/hyundai-kia-wireless-car-charging/ (link as of 6/10/19).

95 https://www.weforum.org/projects/global-battery-alliance (link as of 6/10/19).

96 Ibid.

97 Target Malaria, *Target Malaria Proceeded with a Small-Scale Release of Genetically Modified Sterile Male Mosquitoes in Bana, a Village in Burkina Faso*: https://targetmalaria.org/target-malaria-proceeded-with-a-small-scale-release-of-genetically-modified-sterile-male-mosquitoes-in-bana-a-village-in-burkina-faso/ (link as of 6/10/19).

98 https://link.springer.com/article/10.1007/s10592-019-01165-5 (link as of 6/10/19).

99 Schwab, K. and Davis, N. (2018), *Shaping the Fourth Industrial Revolution*, World Economic Forum.

100 Schwab, K. (2016), *The Fourth Industrial Revolution*, Penguin /Random House, ISBN: 9780241300756.

101 https://medical-data-models.org/ (link as of 6/10/19).

102 OECD (2019), *Regulatory and International Regulatory Cooperation Report.*

103 Ibid. See also McKinsey's Global Institute report (2016), *Digital Globalization: The New Era of Global Flows.*

104 UNHLP on Digital Cooperation (2019).

105 Workshop with GCSP, Ethics and Emerging Technologies.

106 https://www.springer.com/gp/book/9789400713550 (link as of 6/10/19).

107 McKinsey (2019), *Cutting through the 5G Hype: Survey Shows Telcos' Nuanced Views.* Op cit.

108 Kristal, T. and Cohen, Y. (2017), *The Causes of Rising Wage Inequality: The Race between Institutions and Technology*. *Socio-Economic Review*, Oxford University Press, 15(1), pp. 187–212.

109 Dobrygowski, D. (2019), *Why Companies Are Forming Cybersecurity Alliances*, *Harvard Business Review*, 11 September 2019: https://hbr.org/2019/09/why-companies-are-forming-cybersecurity-alliances (link as of 6/10/19).

110 There is growing evidence that populations view cybersecurity as a political concern. For example, Anomali (2019), *Anomali Harris Poll: Ransomware Hits 1 in 5 Americans*: https://www.anomali.com/blog/anomali-harris-poll-ransomware-hits-1-in-5 (link as of 6/10/19).

111 Carr, M., Lesniewska, F., Brass, I. and Tanczer, L. (2018), *Governance and Policy Cooperation on the Cyber Security of the Internet of Things*, 27 March, 2018: https://www.petrashub.org/wp-content/uploads/2018/11/Global-governance-of-the-Internet-of-Things-Report-PDF.pdf (link as of 6/10/19).

112 For example, World Economic Forum (2018), *Advanced Drone Operations Toolkit: Accelerating the Drone Revolution*: http://www3.weforum.org/docs/WEF_Advanced_Drone_Operations_Toolkit.pdf (link as of 6/10/19).

113 For example, Fan, Z. and Gupta, A. (2018), *The Dangers of Digital Protectionism*, *Harvard Business Review*, 30 August 2018: https://hbr.org/2018/08/the-dangers-of-digital-protectionism (link as of 6/10/19).

114 https://www.un.org/en/pdfs/DigitalCooperation-report-for%20web.pdf (link as of 6/10/19).

115 https://www.gsma.com/betterfuture/wp-content/uploads/2019/02/DigitalDeclaration_overview.pdf (link as of 6/10/19).

116 http://www3.weforum.org/docs/48423_Whether_Blockchain_WP.pdf (link as of 6/10/19).

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World Economic Forum
91–93 route de la Capite
CH-1223 Cologny/Geneva
Switzerland

Tel.: +41 (0) 22 869 1212
Fax: +41 (0) 22 786 2744

contact@weforum.org
www.weforum.org