Chapter 10. Technology governance and the innovation process

By

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Innovation reaps major benefits for economies, but some emerging technologies carry public concerns and risks. However, governing and steering emerging technologies to achieve good outcomes, while important, remains difficult. This chapter first examines how governance of emerging technologies should be recast from post-hoc regulation to approaches that engage the process of innovation itself. It then successively discusses three policy instruments that show promise as a means of addressing societal goals, concerns and values during the innovation process: participatory agenda-setting, co-creation (e.g. in the form of test beds), and value-based design and standardisation. The final section draws the main policy implications of adopting a more upstream approach to technology governance.

Embedding governance in innovation processes

Technological innovation is a major engine of productivity, economic growth and well-being. Its development is shaped by a mix of market, social and political forces. In many parts of the world, people live longer, healthier, and more comfortable lives because of the fruits of innovation. Governments around the globe seek to stimulate innovative activity through the orchestration of innovation systems and the setting of appropriate regulatory frameworks that engage market dynamics as well as the diversity of innovation needs and forms (OECD, 2010a).

While essential for addressing some of society's most pressing challenges, innovation can also have negative consequences for individuals and societies, as witnessed in previous waves of industrial revolution or in current debates around digitization, data privacy, and artificial intelligence. Indeed, the profound and ambiguous societal implications of emerging technologies bring them to the forefront of popular media and political debate. Blockchain technology promises a revolution in business models and transaction transparency, but also calls into question decades' worth of global regulation of financial markets (Berryhill et al., 2018). Autonomous vehicles carry enormous potential, but early experiments also highlight the dangers of their use in real-world environments (ITF, 2015). Digital platforms like Uber or Airbnb have begun to revolutionise entire service sectors, but have also raised concerns about new inequalities, and have occasionally been met with fierce resistance (OECD, 2016a). New developments in bioengineering, including gene editing and do-it-yourself biology kits, have recently triggered a series of global discussions about the future, and a potential ban on CRISPR-Cas9 and other gene-editing technologies (Garden and Winickoff, 2018a). Preventing, correcting or mitigating such potential negative effects while still allowing for entrepreneurial activity to flourish and reaping the benefits of innovation is a key challenge facing policy makers today.

Appropriate governance of emerging technologies is hence the proper task of governments because of the former's capacity to alter – and potentially disrupt – existing social orders, often in uncertain ways. Governing innovation in such ways as to limit potentially negative effects in innovation represents a complementary function of governments in well-functioning innovation systems, in addition to correcting for market, systems, and institutional failures (OECD, 2010; Bozeman, 2002; Smits and Kuhlmann 2004). It balances private sector interests and market dynamics with public good consideration and democratic legitimacy. This task has become more important, yet more difficult, as technology itself has become more complex, pervasive, and convergent. Some have argued that recent development around digital technologies – and their convergence with biological and other material systems – may mark a turning point for reconsidering the role of technology governance (The Economist, 2016; Marchant and Wallach, 2017).

The private sector, too, is increasingly voicing governance concerns. On 10 April 2018, Mark Zuckerberg, CEO of Facebook, the largest social network in the world and one of its most powerful corporations, was questioned before the United States Congress about failures in data protection, the right to privacy and pernicious uses in election meddling. Throughout the hearing, lawmakers raised a wide array of questions on the relationship between innovation and democracy, corporate responsibility in preserving core constitutional values and the disproportionate power of quasi-monopolies in the digital sphere. As Zuckerberg stated in his response, "My position is not that there should be no regulation. [..] I think the real question, as the Internet becomes more important in people's lives, is what is the right regulation, not whether there should be or not" (CBC, 2018). Recently, Microsoft President Bradford Smith has echoed these sentiments for the case of

facial recognition software, arguing that "We live in a nation of laws, and the government needs to play an important role in regulating facial recognition technology" (Singer, 2018).

These episodes reflect a broader pattern of unease with the power of technology – and its creators – over our lives. They highlight the seemingly unregulated spaces in which innovative companies like Facebook grow from small start-ups to global giants, as well as the difficulties experienced by policy makers in formulating the right questions – let alone exerting appropriate oversight – in a rapidly changing technological landscape. The perception is growing across the public and private sectors that the future of work, democracy and other aspects of social order will require new forms of governance allowing policy makers to respond to technological change in real time (OECD, 2018).

Box 10.1. Definition of technology governance

Building on previous OECD work, technology governance can be defined as the process of exercising political, economic and administrative authority in the development, diffusion and operation of technology in societies (OECD, 2006; Kaufmann and Kraay, 2007; Carraz, 2012). It can consist of norms (e.g. regulations, standards and customs), but can also be operationalised through physical and virtual architectures that manage risks and benefits. Technology governance pertains to formal government activities, but also to the activities of firms, civil society organisations and communities of practice. In its broadest sense, it represents the sum of the many ways in which individuals and organisations shape technology and how, conversely, technology shapes social order (The Commission on Global Governance, 1995; Greene, 2014).

Several recent trends – some governmental and some market-driven – in the governance of emerging technologies are taking an anticipatory approach. Three instruments in particular for "upstream" innovation governance – participatory agenda-setting, co-creation and test beds, and value-based design and standardisation – show promise as a means of addressing societal goals, concerns and values during the innovation process itself. These instruments tend to emphasise *anticipation*, *inclusiveness* and *directionality* as key ingredients for governance, which can help shape technological designs and trajectories without unduly constraining innovators. The following chapter discusses three promising instruments – participatory agenda-setting, co-creation (e.g. in the form of Test Beds), and value-based design and standardisation – to illustrate how process governance can help augment innovation processes to respond to public and policy concerns.

Reframing governance as integral to the innovation process

The governance of emerging technologies poses a well-known puzzle: the so-called Collingridge dilemma holds that early in the innovation process – when interventions and course corrections might still prove easy and cheap – the full consequences of the technology – and hence the need for change – might not be fully apparent (Collingridge, 1980). Furthermore, early interventions can unduly limit technological options before they are adequately explored.

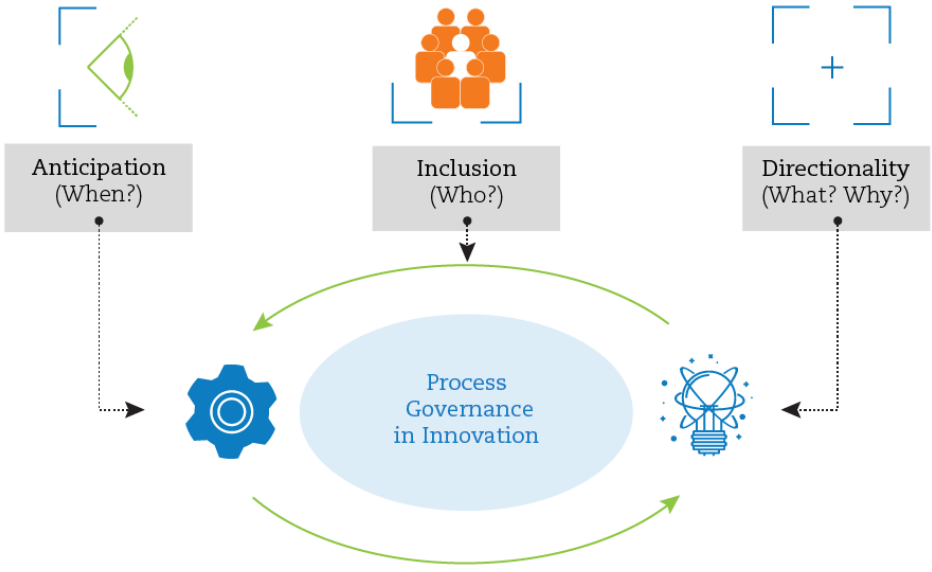
Conversely, when the need for intervention becomes apparent, changing course may become expensive, difficult and time-consuming. Society and developers may have already made substantial investments in adopting a technology, and set in motion certain path dependencies. Uncertainty and lock-ins are at the heart of many governance debates

(Arthur, 1989; David, 2001), and continue to pose questions about "opening up" and "closing down" development trajectories (Stirling, 2008).

In such conditions of uncertainty, traditional regulatory instruments – e.g. risk assessment, product-based standard-setting, export controls and liability – tend to narrowly focus on immediate or readily quantifiable consequences and their management, or enter only after key decisions about technology design have been made. Yet, many of the issues raised by currently emerging technologies are more fundamental and long-term. For example, current developments in artificial intelligence (AI) research might be subjected to rigid classification, performance standards, estimates of economic gains and losses, and export controls; however, the long-term societal and economic implications for populations, health systems, business and society cannot be predicted with any certainty. Similar patterns can be seen in the field of neurotechnology, where embedded devices and brain-computer interfaces are subjected to existing safety and efficacy regimes, but these regimes may not address long-term ethical questions about human agency and mental privacy (OECD, 2017b; Garden and Winickoff, 2018b).

Several emerging approaches in science policy seek to overcome the Collingridge dilemma by engaging concerns with technology governance "upstream". Process governance shifts the locus from managing the risks of technological products to managing the innovation process itself: who, when, what and how. It aims to anticipate concerns early on, address them through open and inclusive processes, and steer the innovation trajectory in a desirable direction. The key idea is that making the innovation process more anticipatory, inclusive and purposive (Figure 10.1) will inject public good considerations into innovation dynamics and ensure that social goals, values and concerns are integrated as they unfold. By locating governance discussions within the vanguard of innovations, it also ensures that policy makers are not be taken by surprise.

Figure 10.1. Three imperatives of a process-based approach to governance



Characteristics of process governance: Anticipatory/upstream

Predicting the path of new technologies is notoriously difficult, whether the context is government regulation, venture capital or academic research. Anticipation – e.g. in the form

of structured foresight and informed planning – is a key concern in many policy circles and boardrooms around the globe. From an innovation perspective, end-of-pipe-approaches can be inflexible, inadequate and even stifling (World Economic Forum, 2018). But can anticipation be a systematic component of innovation governance? How can that be done?

Recently, a range of anticipatory and upstream approaches have emerged that may help explore, deliberate and steer the consequences of innovation at an early stage (Box 10.2; Wilsdon and Willis, 2004). They allow for responding to public concerns or changing circumstances along the development trajectory. From an industry perspective, upstream approaches can incorporate public values and concerns, potentially mitigating potential public backlash against technology (see section 9 on design ethics). In OECD countries, frameworks for upstream governance have entered policy debates, e.g. in the context of the "Anticipatory Governance" pillar within the U.S. Nanotechnology Initiative (OECD, 2012). Likewise, under the major EU research-funding programme, Horizon 2020, the Responsible Research and Innovation (RRI) pillar has attempted to mainstream this approach across all research activities, echoed by recent developments in the United States (Box 10.3). Anticipatory governance also mitigates hubristic tendencies in risk management that one can estimate complex risks and guard against failure with authoritative certainty (Jasanoff, 2003, Pfotenhauer et al., 2012).

Box 10.2. In my view: Professor David Guston on "anticipatory governance"

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The idea of anticipatory governance (Barben et al., 2008; Guston, 2014) is to provide an opportunity to work as productively and pragmatically as possible within the confines of the so-called Collingridge dilemma. To do so, it envisions building three capacities: anticipation, or foresight; integration across disciplines; and public engagement. Building these capacities, both in traditional innovation organisations (like universities and private firms), as well as across society more broadly (in non-governmental organisations and public education), can help create a reflexive approach to innovation that will constantly be re-examining its public purpose and its ability to facilitate responsible changes in society.

Anticipatory governance recognises that at least two changes from current thinking are crucial. One is that governance is not just something that happens in governing institutions like legislatures, courts and regulatory agencies, but that it also happens through the interaction of users with new technologies and through the creative choices that researchers make in laboratories. This "jurisdictional" change means that the bounds of expertise must be expanded from traditional modes, bringing experts in governance into conversation with lab researchers and bringing lay citizens into the conversation altogether.

Two is that anticipation is not about predicting a future state of an innovation, but rather, it is about asking questions about plausible futures so that we may act in the present to help bring about the kind of futures we decide we want. This "temporal" change means that people from many different backgrounds need to work together to imagine futures and begin to build pathways towards them in the present. Neither of these changes resolves the Collingridge dilemma, but together, they give us the best hope of living within it.

Characteristics of process governance: Inclusive/democratic

Publics are normally assigned a passive role in the innovation process, i.e. as end-of-pipe consumers and with a view towards eliciting technology acceptance. This approach has been shown to backfire, e.g. in biotechnology (Irwin, 2001). The benefits of engaging citizens, publics, and systematically excluded actors in policy processes through well-designed exercises, deliberative hearings, panels and comment periods are well-known. Yet, in the domains of science and innovation policy – and particularly in the governance of emerging technologies – these benefits have received much less attention (Jasanoff, 2003; OECD, 2012).

Decades of science and technology studies have shown how value-based choices occur throughout the different phases of the innovation process (Bijker et al., 1987). In shaping what we know, where we go, and how we live and interact, technologies act as a kind of invisible and durable "legislation", as observed by the scholar Langdon Winner (1980) many years ago. If technology designs have "law-like" social consequences, however, then they require some form of democratic accountability. Hence, innovation systems should promote opportunities for public deliberation and participation on the values emerging technologies incorporate, and provide citizens with effective opportunities for appraising and shaping technology pathways (Bozeman and Sarewitz, 2005; Schot and Steinmueller, 2018).

Greater emphasis on public engagement and process inclusivity can therefore help align science and technology with societal goals and needs, a major goal of the Responsible Research and Innovation (RRI) agenda in Europe and elsewhere (Stilgoe et al., 2013; Box 10.3).

Box 10.3. Definitions of RRI in countries of the European Union

- "Responsible innovation means taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe et al., 2013).
- "RRI is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow proper embedding of scientific and technological advances in our society)" (von Schomberg, 2013).
- "RRI is as much a movement to foster practices and cultures among those engaged in supporting and pursuing innovation, as a concern with appropriate regulatory and governance structures. The engagement of publics in determining what the desirable ends of research are, and how innovation processes can achieve these, is also often seen as a crucial part of responsible practice" (Nuffield Council on Bioethics, 2013).
- "RRI is the ongoing process of aligning research and innovation to the values, needs and expectations of society" (European Commission, 2014).

This emphasis goes beyond the widely acknowledged benefits (and biases) of open or user-led innovation, such as pooling external expert knowledge or collective creativity (von Hippel 2006; Chesbrough 2005). It adds an element of democratic legitimacy to innovation while gauging public concerns and adjusting trajectories accordingly such as to avoid potential backlash (OECD, 2012). By making innovation processes more inclusive and democratic, innovation can provide better opportunities to members of disadvantaged

groups, improve the positive impacts of technology for a wider range of actors, and enhance democratic participation in shaping sociotechnical futures.

While the rationale for these engagement mechanisms are increasingly well accepted, their mainstream implementation remains challenging. Who gets to participate how, when, and why in the innovation process? Whose interests predominate? Is the input of expert lead-users more valuable than that of lay citizens? When does public engagement lead to improvement, and when does it begin to hamper innovative activity? Answers to these questions are difficult and highly context-dependent. However, growing experience and literature exist on these questions, and good models can be found across OECD countries (OECD, 2017a, Ch.8). One pathway is to unlock the potential of more open and collaborative forms of innovation through "co-creation" processes, for example in the interaction of disease groups, academic researchers and pharmaceutical companies to develop the next generation of health therapies (Winickoff et al., 2016). This form of inclusion can also enhance the relationship between science and society by building a more scientifically literate, supportive and engaged citizenry.

Characteristics of process governance: Purposive/directional orientation

Commitments to mission-driven versus bottom-up research ebb and flow, and debates about the respective merits and demerits continue apace. In some OECD countries, directionality or "mission orientation" has returned to centre stage (Mazzucato, 2018; OECD, 2016). The challenge of the misalignment between research, commercialisation and societal needs is not new (e.g. in the case of orphan drugs). However, present calls for "directed" and "purposive" transformative innovation display a new level of urgency to better connect innovation to "grand societal challenges" (e.g. the Sustainable Development Goals [SDGs]) (Carraz, 2012; Kuhlmann and Rip, 2014; Schot and Steinmueller, 2016) and respond to the particular needs of emerging economies (Kuhlmann and Ordóñez-Matamoros, 2017).

Mazzucato (2018) suggests that by "harnessing the directionality of innovation, we also harness the power of research and innovation to achieve wider social and policy aims as well as economic goals. Therefore, we can have innovation-led growth that is also more sustainable and equitable." This might point to a stronger role for both the government and the public in defining the goals of innovation and monitoring progress in achieving them. At the same time, mission driven approaches must continue to allow relatively unfettered entrepreneurial activity and provide sufficient market incentives, which points to the challenge of finding the right balance between top-down and bottom-up processes.

Three instruments for process governance in innovation

The three above-mentioned imperatives for an upstream and inclusive approach to technology governance are driving science policies across the public and private sectors, targeting all stages of technology development. A growing number of examples illustrate how innovation should not shy away from societal debates about technological futures: rather, it can actively harness them to improve innovation processes and outcomes.

The following section discusses three instruments of innovation-process governance: 1) participatory agenda-setting for mission-oriented research; 2) co-creation (e.g. in the form of test beds); and 3) design ethics and standardisation phases. All three reflect the dimensions discussed above – anticipation, inclusion and directionality – yet deploy them at different stages and in different ways throughout the innovation process (Table 10.1).

Table 10.1. Process governance in three policy instruments

Imperatives of process governance

	Anticipation	Inclusion	Directionality
Participatory agenda-setting in mission-driven innovation	Anticipate social needs and align innovation by feeding ideas and expectations by the public into new research and development (R&D) initiatives.	Include citizens alongside technical experts, policy makers and companies in bottom-up processes to define R&D priorities.	Clearly articulate the purposes and goals of R&D policies and funding to achieve the desirable sociotechnical outcomes.
Co-creation (e.g. in the form of test beds)	Anticipate potential technical, governance, and public opinion challenges through testing under real-world conditions.	Include users and the other members of the public through open innovation processes at various scales.	Include real-time feedback on desirability and enable small-scale demonstration before broader roll-out in test beds.
Design and standardisation	Design phase interventions to make transparent and promote social values.	Devise multi-stakeholder models to balance expert-driven design.	Articulate social values and goals and integrate them with technology.

Participatory agenda-setting and mission-driven innovation

Science and innovation policy have long wrestled with the question of steerability of technological progress and the role of government in innovation. Traditionally, innovation policy has embraced markets for allocating resources to meet individual and collective demands and a limited role for government interference where market failures or distortions exist. This view has been repeatedly challenged by pushes for mission-driven or sector-specific science and technology policies (Stokes, 1997) – a position reflected in recent discussions on innovation's role in the addressing "grand societal challenges (Kuhlmann and Rip, 2014). This tension can be traced back to Vannevar Bush's post-war science policy manifesto, *Science, the endless frontier*, in which he observed that "science is the proper concern of the government" because it can be mobilised to address important societal challenges, while at the same time warning against overt "government controls" beyond what could be called a hands-off funder-facilitator role (Bush, 1945; Stokes, 1997; Pfotenhauer and Juhl 2017).

Growing concerns about how to best mobilise innovation for the public good and overcome the apparent lack of bold progress have led to calls for a new era of mission-driven research. Scholars like Mariana Mazzucato (2013) have evoked the era of large-scale mission-driven research after the Second World War ("going to the moon") to argue that governments should act "entrepreneurially" and "boldly lead the way with a clear and courageous vision," reaping the benefits of high-risk investments. The more proactive perspective of Mission-driven Innovation 2.0 reflects concerns that science and innovation do not sufficiently meet human needs and public expectations, which in turn affects their public acceptance.

From a governance perspective, then, a key question is who sets the mission, and within what processes? In contrast to previous attempts at mission-driven research, the current wave emphasises anticipatory and inclusive aspects. Today, governments tend to disfavour purely top-down agenda-setting which relies on elected officials, science advisers and other experts. Instead, they are using deliberative processes to better align innovation strategy and societal priorities. For example, the European Commission's Citizen and Multi-Actor Consultation on Horizon 2020 (CIMULACT) has distilled input from EU citizens in 30 countries into a list of 23 distinct research topics for Europe, partly reflected in the European Union's new Horizon 2020 (H2020) research agenda (Box 10.4).

Thus, participatory agenda-setting becomes an idea space and site for upstream governance that allows policy makers to define the very visions and missions driving innovation (OECD, 2017c). It asks what kinds of missions are worth embracing, and how can democratic processes be established to legitimise them? This approach does not consider political and social concerns as external to the innovation process, to be avoided and silenced, but as essential features of any emerging technology, to be explored and incorporated head-on (Pfotenhauer and Juhl, 2017). In this context, controversies can be harnessed as a strategic resource for innovation, enabling discussions about priorities and the distribution of social responsibilities.

Box 10.4. Deliberative agenda-setting: Two examples

In 2015, the EU-funded project CIMULACT engaged more than 1 000 citizens in 30 countries, along with various other actors, in redefining the European Research and Innovation agenda to make it more relevant and accountable to society. The project encouraged participants to formulate their visions for desirable sustainable futures, debate and develop them together with other actors, and transform them into recommendations for future research and innovation policies and topics. The CIMULACT consortium included 29 European members from organisations active in technology assessment, science dissemination, innovation, research and consulting, co-ordinated by the Danish Board of Technology Foundation. Among other things, CIMULACT identified 23 citizen-inspired research topics drawing on 179 "visions" and reflecting 26 distinct social needs, which have since been partly picked up by the European Commission when defining the H2020 research agenda for 2018-20. These citizen-based topics include greater dissemination and access to healthcare innovations; evolving food cultures in growing cities; and mobilising technology to ensure more balanced work-life models in future work models.

In 2014, the Dutch Government began developing a new strategy for science, the National Research Agenda. To maximise support from different social groups, one of the pillars of the development process was public consultation using digital tools, wherein members of the public were invited to "ask a scientist a question". All residents of the Netherlands could submit questions on the website, and access explanations and key words. The questions were analysed and clustered into 248 groups; 3 conferences were organised to add relevant information and aggregate further some of the questions in these groups. A total of 900 people participated in the conferences, which were organised in disciplinary and multidisciplinary discussion groups over several rounds. A panel of experts further reduced the questions to 140. These questions were then linked to the priorities of different national research organisations and also divided into chapters of the final National Research Agenda: 1) Man, the environment and the economy; 2) the Individual and society; 3) Sickness and health; 4) Technology and society; and 5) Fundamentals of existence. The final research agenda described the linkages between the 140 clustered questions and themes from the H2020 programme. By the time the National Research Agenda was released, more than half of those who had submitted a question had received invitations to lectures, public meetings and online fora from a range of organisations.

Sources: (OECD, 2017c; CIMULACT, 2017; de Graaf et al., 2017)

Co-creation and test beds

"Co-creation" has emerged as a widely desired key resource in current attempts to enhance innovation processes and outcomes. It is an umbrella term that captures a variety of activities where different innovation actors gather under a joint project to achieve a mutually beneficial outcome. Different disciplines have emphasised different aspects of co-creation, such as social robustness, responsibility, collective creativity, knowledge flows and better alignment of innovation with consumer needs. Co-creation already plays an important role in many current science and innovation strategies of OECD countries, e.g. in Japan's Fifth Science and Technology Basic Plan (Government of Japan, 2016). There, for instance, the Japanese Research Institute of Science and Technology (RISTEX) funds co-creation projects featuring collaborative and prospective technology assessment, and convenes multiple stakeholders around common societal problem formulations.[1]

Why can co-creation help improve the governance of emerging technologies? While innovation was long conceived as happening outside the public eye in secretive corporate R&D departments or created by genius inventors in a garage, the trend in recent years has been a consistent move towards more open, co-creative and responsive forms of innovation. For example, "maker spaces" and "fab labs" have sprung up across universities and municipalities, providing experimental and collaborative workspaces and expertise for young innovators, free of charge or for a small fee. The visible trend towards co-creation offers new resources for steering and governing innovation in the making.

Co-creation facilitates the identification of potential technical flaws and governance challenges through direct feedback from diverse actors, which extends the range of inputs beyond traditional experts or select users. It can also reveal potential public concerns through immediate testing under quasi real-world conditions. For example, if the intention is to build social robots for elderly or patient care in nursing homes or hospitals, then information from patients, relatives, nurses, doctors, insurers and facility managers, alongside scientists and engineers, will likely improve their design. It can be tailored to a specific social environment and enhance the acceptability of the technology.

A number of new co-creation instruments have recently emerged that are particularly promising for questions of technology governance. Prominent examples are test beds and living labs, designated spaces for innovation activity and experimental technology implementation. They aim to test and demonstrate new sociotechnical arrangements in a model environment, under real-world conditions (Box 10.5). Co-creation rationales are also increasingly shifting public procurement practices from a market-based to a governance rationale. With public procurement of innovation, the public sector can act as a co-creator by defining public challenges to be addressed through an innovative solution that is yet to be developed. The novelty is that the government purchases a solution that does not yet exist while simultaneously setting the social, ethical and regulatory conditions under which the innovation should operate. For example, in the European robotics consortium ECHORD++, public procurement of innovation was used to co-develop robotics technology involving firms, universities and municipalities to enhance sewer cleaning and hospital care.

Co-creation still poses challenges for researchers, companies and policy makers, including how to mainstream practices across sectors, regions and scales. The European research consortium Scaling up Co-creation: Avenues and Limits for Integrating Society in Science and Innovation (SCALINGS) is presently exploring ways to expand co-creation in 10 countries and 3 different sectors (robotics, urban energy and autonomous driving).

SCALINGS is both investigating the technical challenges of developing innovative technologies and the social challenges of embedding them in diverse governance regimes.[2]

Box 10.5. Test beds: Testing new governance modes for emerging technologies

Drawing on the popular "grand societal challenges" discourse and the growing insight that adequate policy responses to these challenges will require transformations of both technology and society, test beds (and related initiatives like living labs, real-world laboratories and demonstrators) are sites of collaborative invention, testing and demonstration for future technologies and sociotechnical arrangements in a model environment, under real-world conditions. These increasingly prominent types of co-creation practice are deployed across geographical regions and technical domains to foster innovation. (Engels, Wentland and Pfotenhauer, 2018).

Test beds are particularly prominent in the area of energy transition, smart cities and mobility. For example, in September 2017, Canadian Prime Minister Justin Trudeau announced a partnership between Waterfront Toronto and Sidewalk Labs – a start-up under Google's parent company Alphabet – to turn Toronto's waterfront into "a proving ground for technology-enabled urban environments around the world" (Hook, 2017). The initiative aims to integrate self-driving shuttles, adaptive traffic lights, modular housing and freight-delivering robots, in line with a city commitment to "waive or exempt many existing regulations in areas like building codes, transportation, and energy in order to build the city it envisioned." Elsewhere, test beds for autonomous vehicles are flourishing, affecting rural roads, highways and cities alike. Test-bed projects for smart and sustainable cities, whether in South Korea (Songdo), China (Tianjin) or Abu Dhabi (Masdar City), are experimenting with ways to foster new forms of urbanity and innovation, frequently with the ambition of becoming a model for other cities.

Test beds are providing new opportunities to tackle governance issues in innovation. They offer a glimpse at new sociotechnical arrangements in an "as-if" mode of tentative roll-out, identifying not only glitches in the technology, but also societal responses and governance challenges (Engels, Wentland and Pfotenhauer 2018). Test beds can serve as an instrument to co-develop the very rules and regulations needed to cope with new technologies, and to gauge which existing regulations might be detrimental to adoption. For example, the European Energy Forum in Berlin has re-purposed a historical gas-storage facility into a private research campus that develops and tests new forms of energy, mobility and information technology solutions, blending technology creation-and-use environments (Canzler et al., 2017). Here, building, traffic and infrastructural regulations are being experimented alongside tested technologies, with a view towards scaling them across Berlin and beyond. While public policy has primarily focused on lowering local regulatory barriers in test-bed settings, or blurring boundaries between public and private interests, this experimental approach to governance also provides new opportunities to deliberate new rules and regulations in real time in order to direct innovation towards desirable outcomes. It provides a counterpoint to the widespread notion that regulation is consistently unable to keep pace with innovation (Engels, Wentland and Pfotenhauer, 2018).

Design ethics and standardisation phases

Technology-based standards determine the specific characteristics (size, shape, design or functionality) of a product, process or production method. This form of governance can

emanate from both the private sector (e.g. *de-facto* standards in the form of dominant designs) and the public sector (e.g. government regulated vehicle safety standards or mobile phone frequency bands).

Standards are critical for innovation: they define the conditions under which competition takes place, and act as a built-in infrastructure for technology uptake and use within supply chains, markets and society. From an economic perspective, they are desirable as vehicles of efficiency by ensuring interoperability, securing minimum safety and quality, reducing variety, and providing common information and measurement (OECD, 2011). On the other hand, they can also create barriers to entry, distort competition, and be prone to capture. They can also serve as useful vehicles of intellectual property rights (e.g. Blind, 2013), but they also carry the danger of reinforcing monopolistic power and incumbency (Swann, 2000; OECD, 2011).

From a governance perspective, standards are equally important because of their social and ethical implications. Standards "build in" certain norms, values, safeguards and goals into technologies and infrastructures (Bowker and Star, 2000; Busch, 2013; Timmermans and Epstein, 2010). For example, the lack of standardisation for genetic tests (e.g. on cancer risks) may create conflicting diagnoses about an individual's health and required course of action, with downstream effects on who might receive health insurance or be denied coverage because of a pre-existing condition (OECD, 2017b). Emission standards for combustion engines or factories affect public health and the environment, frequently with very unequal distributive effects. The dimensions of airplane seats refer to standardised body measurements, with consequences not only for individuals who do not conform to these measurements, but also for flight safety and economics. Once technological design is standardised – whether in material or code – it shapes human behaviour in a law-like manner and becomes increasingly hard to unseat over time (Lessig, 1999; Winner, 1980). Current technological convergences in production, transportation and energy systems elevate the political stakes of standardisation and integration (OECD, 2017a).

At the same time, careful consideration of product and process standards offers new inroads into the governance of emerging technologies. Recent efforts by technical and policy communities treat standardisation as a point of intervention to incorporate and make explicit certain ethical and political values into the material objects, networks and systems that they are designing.

In nanotechnology, standardisation is seen not just as a means of facilitating commerce through interoperability, but also of promoting health and safety. For example, the "Safety by Design" (SbD) approach seeks to integrate knowledge of potential adverse effects into the process of designing nanomaterials and nanoproducts, and to engineer these undesirable effects out of them (van de Poel and Robaey, 2017; Schwarz-Plaschg et al., 2017). Here, "SbD aims at an integrated and iterative process, where safety information on a certain material, substance or product is integrated from early research and development (R&D) phases onwards" (Gottardo et al. 2017). Drawing on concepts from the construction industry, the approach takes into consideration the projects' life cycle: construction, maintenance, decommissioning and disposal or recycling of waste material (Schulte et al., 2008). As a concept, SbD has been studied extensively in the European projects Nanoreg2[3] and Prosafe.[4]

In AI, concerns about the potential bias of algorithms, the lack of accountability of autonomous systems and potential irreversibility have also sparked debates about design standards. President Emmanuel Macron of France recently called for an anticipatory

approach to governance that would "frame" AI appropriately at the design phase *(Thompson, 2018)*:

> *"Because at one point in time, if you don't frame these innovations from the start, a worst-case scenario will force you to deal with this debate down the line. I think privacy has been a hidden debate for a long time…Now, it emerged because of the Facebook issue. Security was also a hidden debate of autonomous driving. Now, because we've had this issue with Uber, it rises to the surface. So if you don't want to block innovation, it is better to frame it by design within ethical and philosophical boundaries."*

This call was later underscored by the Canada-France statement on Artificial Intelligence following the meeting of President Macron with Prime Minister Justin Trudeau of Canada, where both countries "emphasized the need to develop the capacity to anticipate impacts and coordinate efforts in order to encourage trust" (Government of Canada, 2018).

Notwithstanding these calls, questions remain about how and when such framing should take place, and who should undertake it. Numerous stakeholders, including companies such as Google,[5] have issued statements on ethical principles. The OECD, too, is developing recommendations on the ethics of making and using artificial intelligence. The "ethically aligned design" (EAD) Standards for Autonomous and Intelligent Systems, currently being developed by the Institute of Electrical and Electronics Engineers (IEEE), is another potential way forward.[6] EAD comprises more than 100 sets of recommendations (including standards on algorithmic bias; model process for addressing ethical concerns during system design; and transparency of autonomous systems), which can be utilised immediately by technologists, policy makers and academics. However, most of these standards remain a work in progress. Because the AI community aims to be much more inclusive than in typical standard-setting procedures, the working groups at IEEE have operated as fora for public discussion and debate, as much as for technical work.

With design ethics emerging as a potentially powerful tool for translating values into technology, the question arises about how that process is itself governed. A wide array of governance models exists, from purely private standard-setting to mixed public-private fora, like the International Organisation for Standardisation (e.g. Winickoff and Mondou, 2017). Such bodies can be slow and rigid; they also differ widely in how they develop standards and integrate input from diverse stakeholders. Single countries can sometimes dominate standard-setting processes to press technological advantages.

Relevant communities of engineering practice are in a good position to think creatively about finding and standardising technical solutions. However, different technical communities will bring different goals to the task, which may not necessarily align with others within democratic societies. This underscores the importance of inclusiveness and accountability in standard-setting as a key component of innovation: who sets the standards, within what process, and with what claims to legitimacy? In this sense, standard-setting can serve as a stage within the innovation process where more inclusive, purposive and anticipatory forms of governance can be developed.

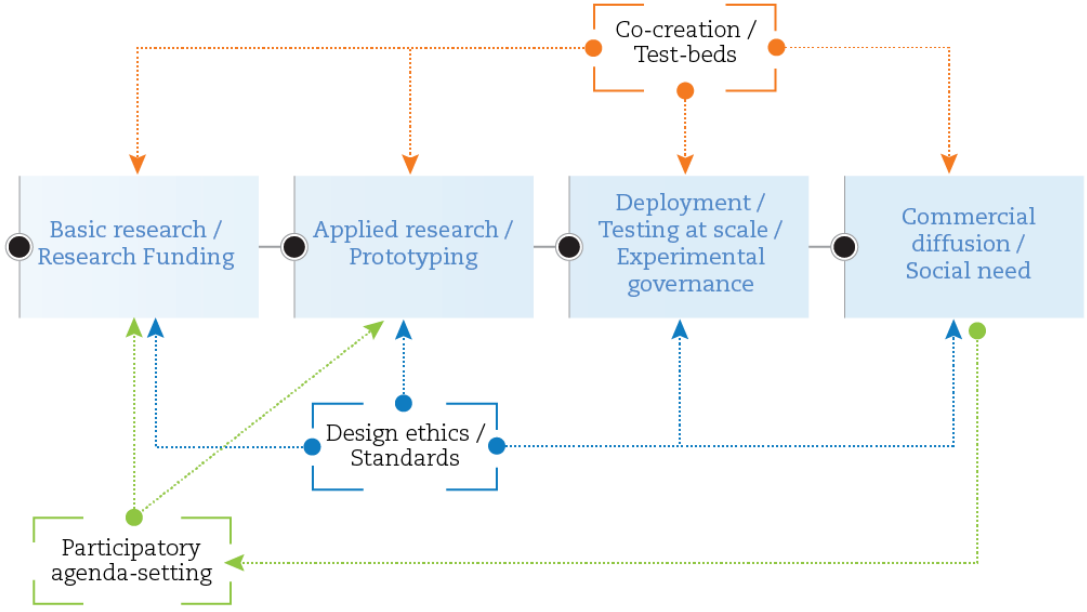
Policy implications

Recent attention to the governance gaps in digital and other emerging technologies has revealed that traditional end-of-pipe instruments might be ineffective for addressing key issues in a timely manner. In OECD countries, both public and private-sector actors increasingly deploy governance instruments at earlier stages and as an integral part of the

innovation process to steer emergent technologies towards better collective outcomes. Anticipation, inclusivity and directionality have emerged as important characteristics for adequate upstream governance of the innovation process. New approaches, such as participatory agenda-setting, co-creation and standardisation, embody these characteristics.

These aspects unfold differently for the three policy instruments discussed above, affecting different stages of the innovation process and shaping outcomes in different ways (Figure 10.2). Participatory agenda-setting draws on structured processes to identify collective needs and concerns, and translates them into research-funding and R&D activities. Co-creation affects R&D practices at various stages and scales, but proves particularly productive in more mature settings (e.g. test beds) where it enables real-time feedback and reveals the governance challenges of emerging technologies. Design ethics scrutinises how ethical and political values are built into technologies; they open up for debate the ways in which emergent technologies will affect society. Note that Figure 10.2 should not be read as a revival of the much-criticized linear model of innovation (Godin 2006, Balconi et al. 2010, Pfotenhauer & Juhl 2017). Rather, it is meant to indicate that process governance can be useful to various types of activity that contribute to innovation, no matter in which order they occur or whatever else might be involved.

Figure 10.2. Upstream governance in the innovation process in three instruments



The undiminished pace of technological change suggests that the need for better upstream governance in innovation will continue to grow, partly to enable responsible diffusion downstream for technologies with uncertain consequences. Governments and businesses should seek to enhance their capacities for anticipatory, inclusive and purposive governance throughout the innovation process, and augment their individual capacities through adequate frameworks for transnational governance.

The previous analysis of three policy instruments indicates that governments can build "technology with and for society" in the following ways:

- continue to experiment with, and expand, participatory forms of foresight and agenda-setting, connecting them to funding organisations and national strategy

bodies; integrate evaluation mechanisms in the design of new governance initiatives from the outset, to improve methods and approaches over time.

- foster opportunities for co-creation among diverse stakeholders for different regions, technologies and scales; exploit opportunities for co-developing new technologies and governance mechanisms, through the responsible use of platforms like test beds.
- use standard-setting to promote the public good and values; support standard-setting processes that function as public fora for democratic deliberation on the governance of emerging technologies, and avoid capture of these fora by narrow interests.
- acknowledge the diversity of innovation practices, needs and rationales across OECD countries, including culturally and politically specific ways of governing emerging technologies; foster co-ordinated international efforts to gather and analyse data and best practices on (upstream) process governance for emerging/converging technologies; build tools and indicators to assess innovation governance against the goals of anticipation, inclusivity and directionality (OECD, 2010).
- develop resources and guidelines for innovation-process governance at an international level; use the capacity for comparison of transnational organisations, such as the OECD or the European Union, to investigate the relative efficacy and context dependency of these process instruments.

Notes

[1] http://ristex.jst.go.jp/hite/en/index.html.

[2] www.scalings.eu.

[3] http://www.nanoreg2.eu.

[4] http://www.h2020-prosafe.eu.

[5] https://ai.google/principles.

[6] The IEEE is a major international association of engineers that produces authoritative technical standards in many fields: https://ethicsinaction.ieee.org.

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