

KNOWLEDGE CO-CREATION IN THE 21ST CENTURY

A CROSS-COUNTRY EXPERIENCE-
BASED POLICY REPORT

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Knowledge co-creation in the 21st century - An international experience-based policy report

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Abstract

The importance of knowledge co-creation – the joint production of innovation between industry, research and possibly other stakeholders, such as civil society – has been increasingly acknowledged. This paper builds on 13 cross-country case studies and co-creation experiences during the COVID-19 pandemic to characterise the diversity of knowledge co-creation initiatives and identify lessons for policy. The paper identifies a strong rationale for policy to support knowledge co-creation because the benefits of successful co-creation initiatives outweigh the initial co-ordination costs. Moreover, knowledge co-creation initiatives can contribute to democratising innovation. Successful initiatives engage all stakeholders and have effective governance and management structures. They also have clearly defined ownership and use rights of the collaborations' outcomes and benefit from favourable conditions to operate, including temporary staff mobility and institutional set-ups that facilitate collaboration and effective communication among participants.

Keywords: knowledge co-creation; collaborative innovation; policy recommendation; COVID-19 pandemic; industry-science linkages; case studies; OECD countries

JEL codes: O31; O32; O35

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Executive summary

What is knowledge co-creation?

Knowledge co-creation is the process of the joint production of innovation between industry, research and possibly other stakeholders, notably civil society. These co-creation initiatives can take different forms, such as projects, mechanisms or diverse institutional arrangements ranging from joint laboratories to industry-led innovation ecosystems.

By encompassing the joint creation or production of innovation with stakeholders from industry, the concept differs from “knowledge exchange”, where academia is the knowledge producer and industry the receiver and user, such as the licensing of intellectual property by companies.

Knowledge co-creation initiatives are essential where collaboration between multiple stakeholders matters and can also help prepare for societal transitions to more sustainable, inclusive and resilient futures.

What are the factors driving successful knowledge co-creation?

Successful knowledge co-creation initiatives bring together complementary expertise to innovate and develop solutions that would otherwise have been impossible. Unlike “knowledge exchanges”, successful co-creation projects facilitate the transfer of tacit knowledge between participants. Some are industry-led or market-driven and consequently have private sector buy-in. Others respond to societal needs and local issues without a commercial component. An important player can be intermediary institutions that take on coordinating roles to help support co-creation initiatives operationally. Digital technologies have enabled co-creation initiatives by supporting collaboration at distance, which proved essential during the COVID-19 crisis, and also data sharing and research collaboration via digital platforms.

Co-creation initiatives that engage civil society allow for the democratisation of innovation processes in a number of ways. First, co-creation initiatives that include beneficiaries from the very start can help orient innovation efforts in directions that are most pertinent and fit-for-purpose. This in turn would support future take-up from users. Second, another benefit of involving civil society is building legitimacy around the innovation effort. Local co-creation initiatives can be more successful than initiatives whose solutions are perceived to ‘come from the outside’. Third, raising awareness and broader communication to civil society around important challenges and the role of innovation in addressing them is another advantage of co-creation initiatives.

These factors, however, only materialise if co-creation initiatives successfully address four core challenges:

- *Engage with key stakeholders.* It is important to build a shared vision, provide clear incentives, clarify contributions and benefits and to set milestones to increase the visibility of progress and motivate all actors involved. Engaging stakeholders is particularly challenging where relations are asymmetrical and hierarchical rather than completely reciprocal and balanced. This requires setting effective incentive and reward schemes.
- *Adopt effective governance and operational management structures.* Depending on the size and scope of the co-creation initiative, the contributions by different actors need to be clearly identified, set out in agreements or contracts that specify the governance structures and need to be monitored by the management of the co-creation initiative.

- *Agree on ownership and exploitation of jointly developed data and intellectual property.* Conflicts about the ownership of outcomes from co-creation initiatives can emerge where the expectations of different stakeholders are very different. An important step in the initial project phase is to agree on and clearly set out the ownership and exploitation of future project outputs. A good practice is to formalise this in partnership contracts.
- *Adjust to changing internal and external institutional environments.* Flexible and agile management in response to the changing demands and requirements of participating institutions helps support the resilience of co-creation initiatives.

What are the strengths of knowledge co-creation in the COVID-19 crisis?

The COVID-19 crisis has illustrated the key role of co-creation mechanisms in Science Technology Innovation (STI) ecosystems' responses to the pandemic, including the development of innovative solutions to COVID-19 challenges. Several policy initiatives supported co-creation initiatives to address the challenges posed by the COVID-19 crisis. Examples include hackathons to generate ideas, the organization of networks to connect experts, the creation of ad-hoc teams and the mobilisation of different kinds of online platforms to enable the mobilisation of a variety of actors (Paunov and Planes-Satorra, 2021^[2]). Some co-creation initiatives in response to the COVID-19 pandemic consisted of actors that had known each other or had collaborated before, building on existing investments in such networks. A well-known example is the joint vaccine development efforts by the University of Oxford and AstraZeneca.

A plethora of co-creation initiatives with a variety of objectives were created shortly after the outbreak of the pandemic in early 2020. These included the creation of expert networks to manage pandemic-related challenges, such as the Pandemic Response Challenge programme in Canada that focused on fast-tracking R&D aimed at specific COVID-19 challenges by bringing together the best Canadian and international researchers. Data-based decision and research support has been also deployed, for example in CORD-19, a resource for scholarly articles about COVID-19 and related coronaviruses available to the global research community. Another type of initiative has focused on community-led co-creation. The EUvsVirus initiative by the European Commission is a prominent example whose hackathon received 2,100 multi-disciplinary submissions; the 117 winning solutions pitched their ideas to 458 industry partners in a "Matchathon" that followed.

Policy implications

Public support for knowledge co-creation is important because of the benefits of successful co-creation once coordination costs involved in setting them up have been addressed. Co-creation is also often essential to effectively tackling wider societal challenges, such as the environmental sustainability crisis and wider resilience to crises.

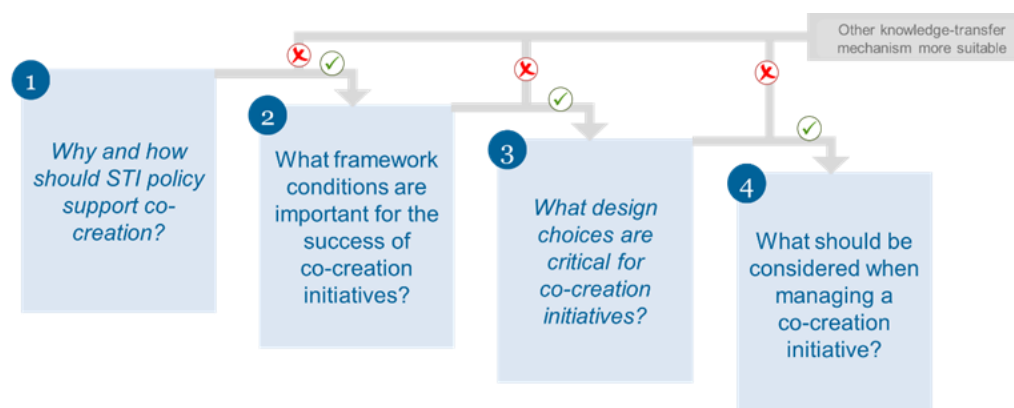
However, public support should target those co-creation initiatives that are most likely to succeed. The co-funding of initiatives with industry is useful to ensure industry engagement, an important condition for the co-creation initiative to succeed. Co-creation initiatives stand a greater chance of success if applied to national priority fields. Favourable framework conditions, including labour policies that allow for mobility across public research institutions and industry will also shape the success of co-creation initiatives.

Design considerations for co-creation initiatives need to take into account whether to involve an intermediary institution, create dedicated co-creation spaces, and how to select the type of initiative and the develop suitable governance models. Important for the operation of a co-creation initiative are regular evaluations that inform decision making, clear data ownership rules, considerate and transparent selection of actors, the adoption of collaborative practices early on as well as the establishment of effective communication strategies.

Policy takeaways

This section summarises the key policy takeaways for knowledge co-creation in the STI policy portfolio, the factors that need to be taken into account when setting up co-creation initiatives and how to conduct successful co-creation activities.

Figure 1. Overview of 4 stages to create successful co-creation initiatives



Source: Developed by authors.

Stage 1: Why and how should STI policy support co-creation?

- **There is a strong rationale for STI policy support to co-creation initiatives.** The main reason for public support is that co-creation can provide more effective industry-science collaboration and help address societal challenges, for example in relation to environmental sustainability and inclusiveness. Co-creation initiatives that provide benefits to society may not emerge without government support because set-up and coordination costs can be too high for individual actors. Engaging civil society also helps “democratise” innovation by involving the public in the innovation process itself.
- **Co-funding of initiatives with industry should be the privileged mode of support.** Co-creation initiatives need to be set up in such a way that stakeholder engagement meets collaboration objectives. Shared financial contributions and active in-kind investments by all participants help build such engagement.
- **Co-creation initiatives should be effectively integrated across funding programmes.** The inclusion of a request to engage in co-creation activities as part of other kinds of support can help build knowledge networks across core fields that receive funding support.
- **Co-creation initiatives that focus on national priorities have a higher chance of success.** If initiatives are related to an important national priority, then it is more likely that favourable legislation and framework conditions are in place. These conditions in turn boost the success of knowledge co-creation projects. Initiatives that are not part of national priorities have fewer opportunities to shape unfavourable framework conditions.
- **Governments should foster international co-creation initiatives** where international collaborations are the most efficient means to address an innovation challenge.
- **Local co-creation initiatives that respond to local challenges are particularly successful ways to engage civil society.** These initiatives make it possible to bring together local actors

from companies, universities, research centres as well as public and private agencies to respond to a specific challenge that directly affects them.

Stage 2: What framework conditions are important for the success of co-creation initiatives?

- **Favourable policy conditions for the international mobility of researchers, resources, data and research results are needed for international co-creation initiatives.** Multiple levels of regulation on the national, transnational and product levels can challenge the optimal use of research funds and affect building capacity to participate in international scientific and technological innovation cooperation.
- **Temporary mobility of research staff is essential to have the human capital that co-creation initiatives require.** Such policies enable staff from universities and companies to move across organisations on a temporary basis and become involved in co-creation initiatives.
- **Whole-of-government approaches are important to foster regulation that concerns co-creation initiatives.** Co-creation can address challenges in the realm of different regulatory bodies. Dialogue and coordination among different regulatory bodies can favour the success of co-creation initiatives. A good practice is the establishment of pan-ministerial groups.

Stage 3: What design choices are critical for co-creation initiatives?

- **Deciding between three types of co-creation initiatives.** Co-creation support can aim at creating a specific project, mechanism or institution. This choice has very different implications for the resulting activities and their impacts. Co-creation projects have a narrower scope and are set up for a specific period of time, while institutions and mechanisms are set up with the longer-term objective of boosting co-creation. While the latter may result into lasting changes in co-creation processes, institution and mechanism-building are costly and will not always result in the improvements in innovation expected from co-creation.
- **Involving an intermediary institution can be useful in specific co-creation settings.** Intermediaries can be important for co-creation initiatives that are starting from scratch and for coordinating actors in large-scale initiatives. Impartiality and a clear mandate from a public agency on the activities to perform are important for intermediaries. Intermediary institutions' financial sustainability over a longer period needs to be ensured, as competencies and the trust of actors are acquired with time.
- **Creating spaces suitable for knowledge co-creation can improve the initiative.** Spaces may range from physical facilities such as joint laboratories to virtual spaces such as digital platforms. These different kinds of co-creation spaces may be combined under one roof, leading to hybrid spaces for co-creation that may include a traditional incubator within a science park, perhaps in the vicinity of a university with a living lab, all of which can be connected with other digital platforms. Attention needs to be paid to developing spaces that will be effectively used by participants in co-creation initiatives.
- **Building an effective operational governance model for the co-creation initiative.** Agreements or contracts that specify governance structures, the role and expected contribution of each partner, as well as the operational procedures and timelines are essential to ensuring success of the co-creation initiative. The establishment and exchange of guidelines and trainings that aim to improve the management structures of co-creation initiatives are good practice. Moreover, flexible processes should allow for adaptation to the circumstances and dynamic nature of the co-creation initiative. For example, the role of co-creation partners may change over time, which requires agile processes to enable co-creation initiatives to develop.

Stage 4: What should be considered when managing a co-creation initiative?

- **Regular evaluations of co-creation initiatives should be conducted to spur their effectiveness and efficiency.** Funders of co-creation initiatives could tie their contributions to the insights of periodical reviews. Regular assessments that spur effectiveness and efficiency are important but also need to take into account that these assessments are costly for participants to engage in and may, if too heavy, discourage participants' future involvement in co-creation activities. Good practice is the development and monitoring of a reasonable number of key performance indicators.
- **Data and innovation ownership rules need to be clearly set out for all actors.** The rules around the ownership of data used or resulting from the activities of the initiative and the resulting innovations need to be clear to all actors before engaging in a co-creation initiative. Good practice is the use of framework agreements that secure the interests of all partners involved.
- **The selection of co-creation actors needs to be considerate and transparent.** It is important to clearly set out the kinds of actors that are to become involved in the co-creation initiative, as their scope can vary from science-industry research partnerships that involve large consortia with over ten companies to bilateral partnerships between one company and one university or research institute. Some co-creation initiatives target only SMEs.
- **All actors in a co-creation initiative need to adopt collaborative practices as soon as possible.** In some co-creation activities, for example those that require funding, prospective partners should jointly write the proposal. This enables them to work together and create relational capital even before the official beginning of the co-creation initiative.
- **Any co-creation initiative should have effective communication channels.** Co-creation actors need to be able to communicate effectively during the co-creation project, in particular if they are at different locations. Digital platforms have been an effective way to enable this. Another aspect is to plan early for the communication of results to audiences outside the co-creation initiative. This is important to get buy-in and anchor the results with potential users or customers of the developed solutions, which maximises future impacts.

1. Introduction

Innovation is increasingly the result of collaborative activities across research institutions, industry actors and stakeholders from the public sector and civil society as it thrives where diverse and complementary knowledge and expertise combine. The mobilisation of science, industry and civil society is also essential to further digitalisation and to trigger the deep transformations that are necessary to accelerate socio-technical transitions (OECD, 2019^[1]; Planes-Satorra and Paunov, 2019^[3]).

Many OECD countries have implemented co-creation initiatives as part of their STI policy toolkits, including in the context of their responses to the COVID-19 pandemic. A case in point is Exscalate4Cov, a public-private consortium made up of 18 institutions from seven European countries. The initiative mobilises supercomputing resources and artificial intelligence to help find solutions to the COVID-19 pandemic.

This paper provides an overview of diverse knowledge co-creation initiatives, with a view towards developing core policy recommendations. The discussion in this paper builds on 13 case studies contributed by country experts that participated in the OECD-TIP co-creation project in 2019-2020. The case study contributions to the project describe policy experiences and provide evidence on specific co-creation projects in a wide range of areas, from autonomising ships in Finland, managing water in cities in Belgium, to fighting the international illegal wildlife trade (see

Table 1).

This paper also benefited from regular discussions with the project's Steering Group throughout the two-year duration of the project, a virtual workshop in March 2020 and a TIP webinar in October 2020, which resulted in insights that are reflected in this paper. It also builds on previous TIP work about knowledge transfer and policies (OECD, 2019^[1]) and the MIT-TIP workshop "Towards effective science-industry co-creation" held in Paris on 5 December 2018.

The remainder of the paper is structured as follows. After the introduction, the paper defines co-creation and illustrates several initiatives (Section 2), it shows why co-creation matters (Section 3), discusses its relevance in the COVID-19 pandemic (Section 4) and describes the typical challenges occurring in co-creation initiatives (Section 5). It concludes with policy implications for the design of co-creation initiatives (Section 6).

Table 1 Overview of co-creation case study contributions to the 2019-20 TIP co-creation project

Country	Author/s	Case study title	Short description
Belgium	Crespin, D.	BrusSEau : Brussel Sensible à l'eau	An "action-research" project (2017–2020) to implement decentralised and participative systems for rainwater management in Brussels to mitigate flooding. It is coordinated by a non-profit organisation, three research centres, a private enterprise and two architecture and urban design offices.
China	Zhou, X.	ASEAN Technology Transfer Center (CATTC)	CATTC is the only ASEAN-oriented technology transfer agency on the national level in China. It was created in 2013 and promotes the transfer of advanced and applicable technologies and promotes the China-ASEAN regional integration of innovation.
Finland	Hyvärinen, J., Kotiranta, A.	OneSea : towards an autonomous marine ecosystem	Created in 2016 to build an autonomous maritime transport system by 2025, OneSea acts as an enabling platform for member companies and other ecosystem participants. It is 44% funded by Business Finland and 56% funded by members.
France	Guilbaud, B.	Bcom : Institute of Technological Research	A private innovation center created in 2012 to boost innovation in digital technologies through co-creation with a diversity of partners that co-invest, share opportunities and risks. The budget of EUR 260 million for

			the center consists of 50% public funding, 26% member contributions and 24% from venture capital or other sources.
Germany	Schimke, A., Lambertus, T., Schmalenberg, J.	Digital AHEAD - Fraunhofer	Since 2019, the digital AHEAD platform has been fostering co-creation between the 74 Fraunhofer institutes and European startups and corporations. Its mission is to empower high-tech ventures and get Fraunhofer technologies into market applications.
Italy	Cristofaro, V., Martinelli, V.	Regional Open Innovation Platform	Launched in 2015, Lombardy Region Open Innovation Platform is a publicly funded collaborative online platform that gathers government, industry, academia and civil participants around strategic research and innovation topics.
Japan	Kawano, H.	AI Technology Consortium (AITeC)	Created in 2015, AITeC has 16 working groups for its member to share their challenges, strengths, deepen mutual understanding, formulate action plans, launch demonstration projects and form collaborations on the deployment of Artificial Intelligence (AI) technologies and the utilization of big data.
Korea	Sohn, Soo J.; Mok, Eunji; Choi, Chi-ho; Park, Jongbok; Park, Byeong Won; Choi, Yong In	Co-creation for fine dust solution	In 2018, the South Korean government enacted the Special Act on Fine Dust Reduction and Management and created a special Committee for Fine Dust Reduction with 40 members from relevant ministries and the private sector. This complements the Center for Particulate Air Pollution and Health, founded in 2014, which conducts co-creation projects resulting in research and solution development. The aim is to develop science and technology-based countermeasures to tackle fine dust.
Norway	Seehus, G.	Triangulum project	The city of Stavanger in the EU H2020 Triangulum project (2015-2020) aimed to enhance the quality of life by delivering efficient and clean transportation services to residents. It focused on innovation actions to solve societal challenges related to carbon emissions in cities by integrating digital technologies, energy and mobility.
Norway	Time, B.	SFI Klima 2050	The Klima 2050 Center (2015-2023) is part of the program SFI – the Centers for Research-based Innovation – by the Research Council of Norway. Its aim is to reduce the societal risks associated with climate change by developing moisture-resilient buildings, stormwater management, blue-green solutions, measures for prevention of water-triggered landslides, socio-economic incentives and decision making processes.
Russian Federation	Meissner, D. Vlasova, V.	Higher School of Economics (HSE) Joint Laboratories	Two joint laboratories, located inside HSE with strong links to the private sector, use machine learning and data analysis methods in new ways. One lab has existed since 2015 and uses these methods to solve theoretical and practical tasks in computer science. The other has existed since 2019 and applies machine learning methods to financial services.
United Kingdom	De Silva, M., Maxwell, S.	Wildlabs Tech Hub: technology to end illegal wildlife trade	Wildlabs Tech Hub is an international programme (2018-2019) that gathered conservation NGOs, firms, public research institutions and government actors to jointly develop and scale technological and data solutions to help mitigate the illegal wildlife trade. It consisted of two projects aimed at (i) accelerating technical solutions to tackle the illegal wildlife trade and (ii) democratize access to data and algorithms to help end wildlife crime.
Research contribution	Rossi, F., Caloffi, A., Colovic, A., Russo, M.	Public innovation intermediaries and digital technology co-creation processes	The study builds on a case base of evidence on selected public intermediaries in France and in the UK. It shows that public intermediaries are able to play their unique role in co-creation processes thanks to, among other factors, their legitimacy and public mandates; reputation and trust over time; and well-functioning evaluation processes.

Sources: All case study contributions are accessible online here [as of 09/12/2020]: <https://stip.oecd.org/stip/knowledge-transfer/case-studies>

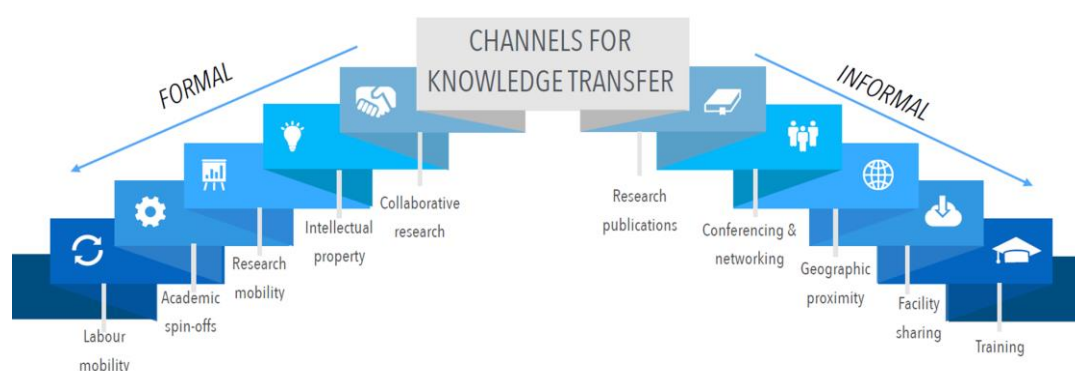
2. What is knowledge co-creation?

2.1. Knowledge co-creation is distinct from knowledge exchange

Knowledge transfer plays an important role in fostering industrial competitiveness and in addressing societal challenges by contributing to transforming scientific knowledge into new products and services. The importance attributed to knowledge transfer relates to the increasing emphasis placed on universities' "third mission" of contributing to socio-economic development, as well as to the benefits that industry can obtain from external sources of knowledge through the adoption of "open innovation" strategies, whereby knowledge flows across organisational boundaries. The increasing complexity of innovation – including the need for sectoral and digital technology expertise in the digital era – render collaborative approaches important.

Knowledge co-creation refers to the process of joint production of innovation between industry, research and possibly other stakeholders, such as civil society. Knowledge co-creation entails systemic relations based on partnerships between different stakeholders and thus moves beyond the linear model of unidirectional knowledge exchange from science to industry where academia acts as the knowledge producer and industry as the receiver and user.

Figure 2. Overview of knowledge transfer channels



Source: OECD (2019^[1])

The concept of knowledge co-creation consequently encompasses some of the channels of interaction between science and industry, including collaborative research projects, joint patenting and publishing activities and public-private partnerships (Figure 2). Public-private partnerships provide a legal structure for different stakeholders from the private and public sectors to pool resources and share risks and rewards. This leads to long-term relationships among participants, who jointly set objectives and combine their knowledge and resources (funding, people, data, equipment and/or facilities) to innovate together based on joint agreements (OECD, 2019^[1]).

Knowledge co-creation defines a specific set of knowledge transfer activities. In contrast, *knowledge exchange* refers to arms-length exchanges of knowledge; a stylised comparison is shown in Table 2. Examples include the process whereby a private firm licenses a patent from a public research institute or where industry research benefits from scientific papers to learn about the results of a research project developed at a university laboratory. Another important difference between knowledge exchange and co-creation is that in co-creation the collaboration also involves partnerships in objective-setting and exploration while exchanges focus more on the latter stages of innovation.

Table 2. Stylised comparison between knowledge exchange and co-creation

Dimension	Knowledge exchange	Knowledge co-creation
Channels of interaction	Research contracts; Academic consultancy; Patenting and licensing; Teaching and training; Publications; Conferences / workshops; Networking	Public-private partnerships; Collaborative research projects; Joint patenting; Joint publishing
Mode of interaction	Transactional; arms-length/distant or nearly serendipitous (such as spillovers from conferencing)	Relational; deep engagement based on joint agreements
Setting of objectives	Set by individual institutions	Jointly set

Source: Developed by authors.

Co-creation is also closely associated to the notion of “open science”, the approach to make the scientific process more inclusive for all relevant actors through the use of digital technologies and new collaborative tools (Dai, Shin and Smith, 2018^[4]; OECD, 2015^[5]). These include open research data, open access to publications, open access to research infrastructure, open-source software, open apps platforms, joint research agenda-setting, prize-based contests, crowdsourcing and crowdfunding.

Co-creation initiatives – such as those that were gathered in the OECD-TIP project on co-creation (see

Table 1) often share a number of characteristics which include the following:

1. **Industry-led or market-driven** – The co-creation initiative responds to the needs of (future) customers as well as market demands, and private sector actors play a lead role in shaping its activities.
2. **Societal engagement** – The co-creation initiative engages with citizens and non-governmental organisations (NGOs). This engagement can take different forms along the innovation value chain. For example, citizens are involved in shaping the directions of the innovation initiative, can participate in the innovation process, such as by helping collect of data, and can help in dissemination of results to relevant communities.
3. **Intermediary coordinated** – An intermediary institution enables the collaboration of innovation actors by managing or coordinating the co-creation initiative. For example, an organisation that acts as an orchestrator in the co-creation initiative brings together different innovation actors.
4. **Challenge-driven** – The co-creation initiative responds to a particular challenge at a local, regional, national or international level. The co-creation initiative unites actors in their aim to address the challenge and mobilises them to jointly develop solutions.
5. **Using digital technologies** – The co-creation initiative uses digital technologies in its activities. This can include, for example, using digital technologies to connect actors across different locations throughout the project lifespan or the creation of digital platforms with interactive workspaces and digitalised project materials.

2.2. Diversity of knowledge co-creation initiatives

The landscape of co-creation initiatives is highly diverse and can involve either the creation of projects, of institutions, or of mechanisms. This section discusses the diversity of co-creation initiatives across dimensions related to the themes that lead to their creation (section 1), actors and governance structures

(section 2), their funding models (section 3), their use of digital infrastructure (section 4) and project goals and expected impacts (section 5).

(1) Drivers, themes and stages of innovation

The reasons and drivers that lead to knowledge co-creation initiatives are manifold and determine their thematic focus and objectives. Industry-led or market-driven co-creation initiatives tend to focus on generating economic returns, typically by means of joint research conducted by research institutions with specific firms or groups of firms. Other co-creation initiatives aim to address a global or a local challenge. The stakeholders involved in the process may include members of civil society and public institutions.

Table 3. Overview of co-creation case studies and their characteristics

Country/ Case study title and reference	Industry-led or market driven	Digital technologies	Challenge-driven	Society engagement	Intermediary coordinated
Belgium/ Brusseau (Crespin, 2020 ^[6])			primary	primary	
China/ CATTC (Zhou, 2020 ^[7])			secondary		primary
Finland/ OneSea (Hyvärinen and Kotiranta, 2020 ^[8])	primary				primary
France/ B<>com (Guilbaud, 2020 ^[9])	primary	primary			
Germany/ AHEAD (Schimke, Lambertus and Schmalenberg, 2020 ^[10])		primary	secondary		
Italy/ OI Platform (Cristofaro and Martinelli, 2020 ^[11])		primary		primary	
Japan/ AITeC (Kawano, 2020 ^[12])		primary			secondary
Korea/ fighting fine dust (Sohn et al., 2020 ^[13])			primary		
Norway/ Triangulum (Seehus, 2020 ^[14])			secondary	primary	
Norway/ Klima2050 (Time, 2020 ^[15])	secondary		primary	secondary	
Russian Federation/ HSE Joint labs (Meissner, 2020 ^[16])	secondary	primary			
UK/ Wildlabs techhub (De Silva and Maxwell, 2020 ^[17])		primary	primary	secondary	secondary
Research Contribution/ public intermediaries (Rossi et al., 2020 ^[18])	secondary			secondary	primary

Source: OECD-TIP co-creation project steering group

Co-creation initiatives also differ with regard to their thematic focus. Some projects focus on a single discipline while others explicitly adopt a multidisciplinary approach to tackle a single problem from a

variety of perspectives. This multidisciplinary or “systems integration” approach is becoming increasingly important given the interconnections between key global sustainability challenges, such as climate change, energy and water supply (Liu et al., 2015^[19]). For example, the Future Earth project – a global network of scientists, researchers and innovators collaborating for a more sustainable planet – focuses on systems-based approaches to deepen our understanding of complex Earth systems and human dynamics across different disciplines.

In addition, there are differences across co-creation initiatives with respect to the stage of the innovation cycle that they focus on. Co-creation initiatives may range from knowledge exploration to knowledge exploitation. Some concentrate on agenda-setting, formulating joint missions and on technology roadmaps shared by a broad range of stakeholders, while others focus on the final delivery and scaling up of the technology developed.

(2) Actors involved and governance structures

Some co-creation projects are established as bilateral public-private partnerships between one company and one university or public research institute, while others may be formed as large consortia involving dozens of partners from academia, industry, civil society, and/or government. Some projects are implemented in a specific region or country, while others involve international partners. An example that focuses on bilateral partnerships is TKI (Top Consortia for Knowledge and Innovation) in the Netherlands, a public-private partnership between industry, knowledge institutions and public authorities across the nine priority sectors designated by the government. Box 1 describes a variety of co-creation projects under way at the Massachusetts Institute of Technology (MIT).

The drivers, themes and stages of innovation also affect the types of actors involved. Co-creation initiatives in clinical research often involve patient associations or individual patients, while in the field of social sciences they often involve civil society (OECD, 2016^[20]). Interdisciplinarity involves a variety of stakeholders (large firms, SMEs, entrepreneurs, universities, research institutes, civil society organisations, government agencies, etc.). For example, in the Industry–University Cooperative Research Centers (IUCRC) in the United States, around 60% of institutions that partner with universities and research institutes are large corporations, 20% are smaller enterprises and 20% are other federal/state agencies, as well as NGOs.

A key feature of some co-creation initiatives is that they bring together actors with complementary expertise. The selection of partners with knowledge, skills, resources, networks and funding was a key success criterion of the Wildlabs Tech Hub in the UK, an initiative aimed at developing and scaling the best technologies to stop the illegal wildlife trade by catalysing collaboration across private and public partnerships. During the design of the co-creation model, each partner had a specific role to play. This included international conservation NGOs, such as the World Wildlife Fund, as well as private and public sector partners, including Amazon Web Services, the Digital Catapults and the UK Foreign Commonwealth Office (De Silva and Maxwell, 2020^[17]). The Triangulum Project in Norway brought together experts on energy, mobility and ICT, and in the case of the Brusseau project in Belgium, transdisciplinary collaboration in the areas of hydrology, water technology and management has enabled it to embrace a greater vision and to strengthen project results (Seehus, 2020^[14]).

The role of actors in a co-creation initiatives may evolve over time. Several case studies highlighted the changing roles and involvement of co-creation actors over the course of the co-creation project timeframe. The case study on the OneSea maritime business ecosystem in Finland exemplifies flexible and bottom-up styles of working, which allows ecosystem members to join and leave the ecosystem as they wish (Hyvärinen and Kotiranta, 2020^[8]). In the case of SFI Klima 2050 in Norway, two research institutions played a lead role in the initiative to create the centre which is now run by a diverse consortium of 15 partners from the construction industry, public sector and governmental actors (Time, 2020^[15]).

The governance structure, coordination of activities and relationships between partners also differ across projects. They depend on the financial to human resource contributions of actors, in addition to the provision of facilities, equipment, data and on how the coordination of the project is organised. A co-ordinating institution that is independent, skilled, experienced and committed team has proven a particularly useful way to coordinate co-creation. This was the case for the technology research institute *bcom* (France) which resulted in an increasing involvement of actors and avoiding conflicts of interest (Guilbaud, 2020^[9]). The OneSea case study (Finland) points to the important role of the orchestrator company that needs suitable skills to effectively bring together the actors in the business ecosystem (Hyvärinen and Kotiranta, 2020^[8]).

Box 1. MIT Co-creation laboratories

MIT (Massachusetts Institute of Technology) has established various co-creation laboratories with different constellations of partners. Some of them, such as the Climate CoLab, involve a large number of firms, research institutes, multilateral organisations, government agencies and NGOs as sponsors or collaborators, reaching out to a global community of researchers and innovators through challenge-driven contests to address climate change. Others are established through a partnership with just one firm, such as the MIT-IBM Watson AI Lab or the MIT-Boeing Kendall centre, with a local county or a foundation such as the Global CoCreation Program at the Institute for Medical Engineering and Sciences at MIT. The Co-Creation Studio, a new initiative at the MIT Open Documentary Lab, focuses on collaborative and immersive storytelling. Using different media methods, co-creation occurs within communities, across disciplines and with non-human systems using AI.

(3) Funding models

Co-creation initiatives have different funding structures, and differ by the extent of public funding support that they receive. The traditional policy approach to promote science-industry collaboration in innovation has focused on offering financial grants to joint research projects or to the creation of institutions for co-creation, conditional on the establishment of consortia between academic researchers and firms. The rationale behind this approach is to overcome market failures and systemic inefficiencies that hamper the propensity of organisations to cooperate. Over the years, these kinds of collaborative grants have been widely adopted by governments.

The duration of public support differs across projects. Both the Industry-University Cooperative Research Centers (IUCRC) in the United States and the Research Campus in Germany receive funding for up to 15 years divided into three 5-year phases. In the case of the Swedish Strategic Innovation Programmes (SIP), each programme consortium is subject to a review process every 3 years, which will determine whether it will continue to receive funding, up to a maximum of 12 years. In Austria, Christian Doppler Association (CDG) Laboratories are established for a maximum of seven years, split into three periods of two, three and two years; they can only enter the subsequent period after passing a scientific evaluation.

(4) Leveraging (digital) technologies and multidisciplinary managerial competences

Regarding technology potential, digital platforms facilitate co-creation in a variety of ways, allowing for new modes of collaboration at a distance between a large number of partners to solve specific technological problems. Examples include IdeaConnection, InnoCentive, Innoget, Kaggle, Ninesigma,

Presans and Yet2, among others. These platforms create opportunities for firms and research institutes to identify potential partners, thus increasing transparency and reducing transaction costs. For instance, InnoCentive allows businesses, governments or civil society organisations to raise questions (“challenges”) and interact with more than 380,000 registered users (“problem solvers”). Other platforms are more specialised, such as Kaggle, which focuses on using new data sets made available through the platform to find solutions to specific challenges.

A number of digital platforms often target grand societal challenges and facilitate the engagement of civil society. Take, for example, recent projects developed through Ninesigma: “Keep plastics out of the ocean”, “Make sustainable chemicals with corn”, or “Re-use heat from wasted energy” (NineSigma, 2019^[21]). Similarly, some of the challenges recently launched through InnoCentive include: “Polio eradication: addressing anti-vaccination propaganda on social media in Pakistan”, “Increasing the number of electric vehicles on the road”, or “Mitigating the environmental impact of large photovoltaic plants” (InnoCentive, 2019^[22]). In addition, a number of crowd-funding websites for scientific research have emerged (e.g. OSSP, MyProjects-Cancer Research UK, StartNext, Experiment.com), as well as other digital platforms to share research data, processes and results (e.g. Open Science Framework, Open Notebook Science, AsPredicted).

In the early days of the COVID-19 pandemic in 2020, the use of digital technologies was a popular way to engage actors in collaborative innovation activities. A range of co-creation initiatives were created, including online platforms – such as Solidarité COVID-19 that aimed at engaging actors in French-speaking projects or CrowdVsCovid, a platform to develop and test citizen science projects across countries – to networks which set out to connect experts, such as the Fast Expert Teams vs COVID-19 in Finland or the tech4covid19 technology community in Portugal (Table 4).

Digital technologies also enable novel ways how co-creation initiatives can be managed. For example, the digital Fraunhofer AHEAD platform is a data-enabled platform which continuously monitors all co-creation projects regarding their challenges, activities and progress. In doing so, it fosters co-creation between the 74 Fraunhofer institutes and European start-ups and companies (Schimke, Lambertus and Schmalenberg, 2020^[10]). Similarly, the China-ASEAN Technology Transfer Center operates an information platform to manage the supply and demand of technology transfer projects, disseminates information on conferences and provides support services (Zhou, 2020^[7]).

(5) Project goals and expected impacts

Co-creation initiatives’ impacts differ depending on their objectives, but often include the following core priorities.

First, an important objective of many initiatives is to enhance knowledge exchange. In the case of the German Research Campus initiative, the 2012-2016 evaluation concluded that the programme has been “assessed positively by companies and the campus management, because it enables an interdisciplinary collaboration that would not be possible otherwise” (...) “allows work on highly complex issues” (...) “has a long-term nature which is a decisive advantage and a key differentiator to other support measures” (Koschatzky and Stahlecker, 2016^[23]).

Second, many aim to create social and economic value (De Silva et al., 2021^[24]). The latter is defined in different ways, including the creation of jobs, such as in the case of CoLabs in Portugal. Evaluations of the IUCRC programme in the United States found that the programme has led to an increase in the quantity and quality of R&D activity carried out by universities by triggering additional private funding for university-led R&D projects (worth about 8-10 times NSF funding), leading to an increase of IP applications, licensing contracts and spin-off companies (NSF, 2019^[25]).

Third, some co-creation initiatives aim to raise awareness and create public understanding on issues such as “fine dust” by means of educational programs, forums and public discussions, as in the case study from Korea (Sohn et al., 2020^[13]). Similarly, the communication project activities and outcomes in the Triangulum project had educational effects and raised awareness among citizens regarding the

importance of, for instance, using good energy sources. This information was disseminated via public seminars and videos that were shown on public screens, in cinemas and via social media in Stavanger (Seehus, 2020^[14]). The case study on the Wildlabs Tech Hub reports the creation and promotion of showcase videos in order to raise awareness on fighting the illegal wildlife trade (De Silva and Maxwell, 2020^[17]).

Table 4. Examples of select co-creation COVID-19 online platforms and networks

Name	Focus	COVID-19 impact	Lead institution/s	Country
Colabcr	Create OI community	Design and produce medical protection supplies, detection / screening tests, design and manufacture assisted ventilation devices, support laboratories with PCR capabilities.	Ministry of Science, Technology and Telecommunications & National Learning Institute	Costa Rica
Fast Expert Teams vs Covid-19	Connect experts	Combine experts from universities, private and public sector organizations and ministries in voluntary pro bono expert networks.	5 Finnish universities, 3 Finnish ministries, Research centres, a regional council and private sector actors	Finland
OpenCovid19 Initiative	Develop+share open source solutions	A program that develops open-source and low-cost tools and methodologies that are safe and easy to use in response to the COVID-19 pandemic.	JOGL, decentralized open research and innovation laboratory	France
Solidarité Covid-19	Engage actors	Enable all contributors to share their ideas and exchange on initiatives and projects that they consider effective in combating the crisis	Organisation internationale de la Francophonie	French-speaking countries
tech4covid19	Create expert teams	A network of volunteer specialists to solve COVID-19-related problems.	3000+ engineers, designers, marketers, health professionals, among other specialists	Portugal
CrowdVsCovid	Build citizen science projects	Development and beta testing of a Citizen Science Project Builder, DIY crowdsourcing platform by a team of citizens and scientists from research institutions in Switzerland, France, Italy, Spain, and the UK.	Citizen Science Center Zurich	Transnational

Source: COVID-19 Watch Survey [<https://stip.oecd.org/covid/>] and desk research

3. What are the factors driving successful knowledge co-creation initiatives?

This section discusses the core factors that maximise the potential of co-creation activities to contribute to innovation, engage civil society and address societal challenges.

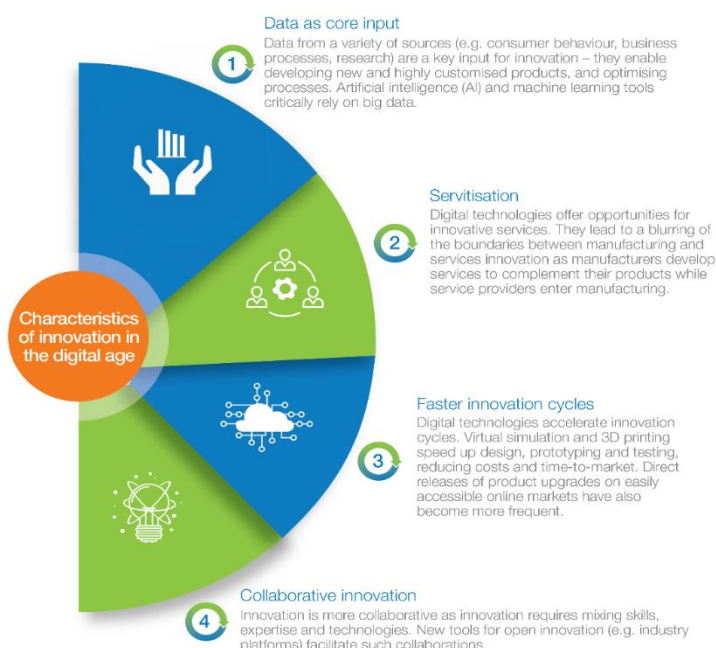
3.1. The contributions of co-creation to innovation

Co-creation is a powerful mechanism to generate innovation as it combines the diverse expertise of contributing actors that facilitates the transfer of tacit knowledge. This is because co-creation initiatives bring together actors and actively involve them in the innovation process from the very beginning to feed into the innovation process. This is in contrast to transaction-based knowledge transfer that aims to exchange knowledge codified in licenses or patents. Another consequence is that stakeholder involvement in research processes enhances the applicability of research and the chances of successful

uptake. It may also facilitate the better alignment of scientific progress with the needs of industry and/or society.

Co-creation can also speed up innovation in the face of disruptive digital technologies such as big data analytics, artificial intelligence (AI), or the Internet of Things (IoT). The need for more collaboration across different types of actors is indeed one of the characteristics of innovation in the digital age (Figure 3), as innovation in the new context often requires skills that go beyond traditional sectoral or disciplinary competences or the boundaries of universities and industry (e.g. human capital, finance, infrastructure) (OECD, 2019^[26]).

Figure 3. Characteristics of innovation in the digital age



Source: OECD (2019^[26])

As in sustainable development challenges, the development and uptake of new digital technologies often requires more intense and long-term collaborations between science, industry and civil society. Moreover, co-creation initiatives can bring valuable secondary benefits in addition to the outcomes of the co-creation activity itself. The skills and innovation capabilities of all actors involved can benefit from exchange with others. Also, the network that is built in the context of co-creation initiatives can prove an asset for future innovations. This proved to be the case for the Wildlabs Tech Hub's network (De Silva and Maxwell, 2020^[17]). The co-creation initiative may also foster the sharing of data and results among project participants and possibly to the wider public.

Table 5 provides some relevant examples of co-creation projects focusing on digital technologies.

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Table 5. Examples of co-creation initiatives for digital transformation

Initiative	Description	Participants/ Size	Subjects	Project examples
European Innovation Partnership on Smart Cities and Communities (EIP-SCC)	Platform supported by the European Commission that connects cities, industries, SMEs, investors, researchers and other smart city actors.	6000+ partners from industry, SMEs, finance and research, from the EU and neighbouring countries. The initiative has 82 smart cities projects across the EU. The initiative has matched EUR 585 million of investor funds as of May 2021.	Infrastructures, technologies and services in key urban sectors (transport, buildings, energy, ICT).	Intelligent Mobility For Energy Transition (IMET): The objective is to create a local innovation ecosystem that supports pilots, demonstrating how smart mobility solutions can contribute to the energy transition. Nissan Europe is in the lead providing its expertise in electric vehicle and battery technology; cities in the initiative commit to contribute to the deployment of intelligent mobility by delivering supporting policies, planning and required permissions; and industry and academia collaborate as delivery partners by providing complementary expertise, products and services.
Microsoft Research Centers	Research labs around the world where Microsoft researchers collaborate with academics, scientists and engineers in diverse research areas.	There are 10 labs worldwide: the Applied Sciences Lab, Microsoft Quantum Research and Microsoft Research AI in Redmond (USA); and 7 Microsoft Research Labs located in Beijing (China), Cambridge, (UK), Bengaluru (India); Cambridge, MA (USA), New York City (USA), Redmond (USA) and Montréal (Canada).	Research and applied technologies in the following subjects: Artificial Intelligence; Systems (e.g. quantum computing); Theory (e.g. deep learning algorithms); Other sciences (e.g. medical, health & genomics).	Sonoma: The project aims to develop an autonomous system that can operate indoor farms efficiently and reliably. With this objective, the project combines existing domain knowledge (e.g. crop modelling, greenhouse climate modelling, and controlled environment agriculture best practices) with modern machine learning algorithms.
MIT-IBM Watson AI Lab	The MIT-IBM Watson AI Lab is a joint research lab founded in 2017 by MIT and IBM that focuses on AI research.	MIT faculty and IBM researchers. The lab is funded by IBM with a USD 240 million commitment over 10 years (2017-2027). In 2019 four additional firms joined as members (Boston Scientific, Nexplanon, Refinitiv and Samsung).	It is currently developing 80 AI project focusing on fundamental AI research in four areas: AI algorithms; Physics of AI; Application of AI to industries; Advancing shared prosperity through AI.	Getting the most from electronic health records (EHRs): EHRs facilitate clinical decision-making. MIT and IBM scientists are working to help physicians discover insights from EHRs much faster by using AI. They have already developed large-scale databases and trained deep learning models to develop a new method for facilitating the question-answering processes based on EHR data.
RUGGEDISED	Project funded by EU's Horizon 2020 to test, implement and accelerate the smart city model across Europe.	Businesses, research centres, and the administration of six cities (Brno, Gdansk, Glasgow, Parma, Rotterdam and Umea) are currently developing 32 smart solutions. It has a cluster of 30+ partners from multiple sectors and countries.	ICT, e-mobility and energy solutions to design smart, resilient cities.	Glasgow – Energy demand management technology: Residential and municipal properties linked up to a smart grid and a central energy demand management system to build up an overview of the domestic energy scenario and explore ways to optimise energy consumption.

Source: Authors' elaboration based on the STIP Compass database and official programme websites.

3.2. Advantages of engaging civil society

Co-creation initiatives that engage civil society – such as local communities and non-governmental organisations (NGOs) – have proven advantageous for developing innovations, particularly when addressing local challenges and major societal challenges. At the local level, challenges that are

affecting citizens' lives provide a strong impetus for the mobilisation of civil society actors in co-creation initiatives. An example includes the BrusSEeau initiative in Brussels. Hydrological Communities (HCs) were created that provided citizens with equipment to take water measurements. These, also referred to as 'living labs', were adapted to local specificities (Crespin, 2020^[6]). Another way of engaging civil society was demonstrated by Triangulum Project in Norway (2015-2020). The initiative held, among other activities, a competition for students to become involved in the design of green buses (Seehus, 2020^[14]).

Co-creation initiatives address societal challenges, such as those related to COVID-19 and other diseases, climate change and sustainable development. Some co-creation initiatives operate as global networks with a strong role for international organisations and NGOs, in addition to private firms and researchers. Examples include the Climate CoLab, an open platform developed by the MIT Centre for Collective Intelligence, which brings together over 115,000 people to work on and evaluate plans to reach global climate change goals, and Future Earth, an international network of scientists and innovators, which aims to foster research and innovation to support green transitions (see Table 6 for more detail).

Table 6 Examples of co-creation initiatives to address climate change challenges

Name	Description	Participants	Subjects	Project examples
Climate CoLab	Open problem-solving platform where a growing community of over 115,000 people work on and evaluate plans to reach global climate change goals.	Project developed by the MIT Centre for Collective Intelligence. They have issued 100+ contests funded by different sponsors (e.g. National Science Foundation, Argosy Foundation, and corporate sponsors of the MIT Center for Collective Intelligence).	Global climate change (e.g. lower carbon emissions, climate risk insurance, land use, resilient sustainable transformation for least developed countries).	Contest webs. People with a broad range of expertise are welcome to submit, evaluate, and select proposals for what to do about various aspects of the climate change problem. One of the contests, for instance, aims to find solutions to restore degraded landscapes, helping communities in Least Developed Countries (LDCs) become more climate resilient.
Future Earth	International network of scientists and innovators whose mission is to accelerate transformations to global sustainability through research and innovation.	Future Earth harnesses the experience and reach of thousands of scientists and innovators from around the globe. This global community is spread over a series of networks and governing and advisory bodies. Future Earth forms strategic partnerships with international organisations that support global sustainability research and action.	Systems-based approaches to deepen our understanding of complex Earth systems and human dynamics across different disciplines. Aims to develop the knowledge and tools that government, communities, and companies need to meet the Sustainable Development Goals.	AIMES (Analysis, Integration & Modelling of the Earth System): This is one of the 20 Global Research Projects developed by Future Earth. It focuses on (i) the functioning of global biogeochemical cycles, including interactions and feedbacks with the physical climate system; (ii) The interplay between human activities and biogeochemical cycles, both in the past and into the future; (iii) How the biogeochemical cycles function on different time scales.

Source: Authors' elaboration based on the STIP Compass database and official programme websites.

These participatory co-creation initiatives democratize innovation efforts, tackle a variety of challenges and support achieving the following goals:

- **Increase relevance.** Stakeholders who are expected to benefit from an innovation are actively involved in its creation to ensure it is fit-for-purpose and pertinent. These initiatives democratise the research decision-making process, possibly offer opportunities to do research/innovation in areas that contribute more to society, generate a sense of ownership of the research/innovation process, and therefore can be an effective mechanism for the subsequent adoption of the research results and innovations (Nature, 2018^[27]).

- **Raise awareness and educate.** Civil society involvement during the development process ensures citizen awareness. For example, co-creation initiatives have been used to inform the citizens on the importance of using good energy sources, the health dangers from fine dust or about the safety and dangers of 5G networks. A diversity of methods are used for this purpose. For example, Korea's Center for Particulate Air Pollution and Health organised educational programs, forums and public discussions to raise awareness on the issue of fine dust and on possible solutions (Sohn et al., 2020^[13]). The Triangulum project in Stavanger (Norway) and Wildlabs Tech Hub (UK) produced videos that were streamed in cinemas and social media platforms to raise public awareness (Seehus, 2020^[14]; De Silva and Maxwell, 2020^[17]).
- **Support and endorse.** Involving civil society actors in co-creation initiatives enables them to influence it, which creates buy-in from future users of their resulting innovations. For example, Cope et al. (2017^[28]) identify support from patient groups as instrumental to the success of the RA-MAP Consortium a group of more than 140 individuals affiliated with 21 academic and industry organisations that focus on genomic medicine in rheumatoid arthritis, in generating a set of innovative treatments.

Co-creation is an important mechanism for implementing systems transformation approaches in practice by mobilising science, industry and civil society to jointly introduce transformations. According to Olsen et al. (2016^[29]), the involvement of advocacy groups, as representatives of stakeholder concerns, is beneficial for research consortia as they improve the generation of potential solutions and provide legitimacy. This is the case in consortia that are addressing societal challenges such as climate change adaptation and managing future crises – as illustrated by the experience of the COVID-19 crisis (OECD, 2020^[30]).

4. Co-creation during the COVID-19 pandemic

This section sketches the roles of knowledge co-creation in the STI response to the COVID-19 pandemic by exploring the co-creation initiatives that emerged, particularly in the early stages of the crisis, when quick responses building on complementary expertise were urgently needed. Some of these types of initiatives, such as hackathons and fast-track competitions, may become more widely used instruments in governments' policy toolkits to stimulate co-creation. The wider engagement of civil society actors in STI activities may also be embraced further after the pandemic. The benefits of this more collaborative approach is important to achieve ambitious goals now on the policy agenda, such as building carbon neutrality. The pandemic also illustrated how digital tools can help mobilise civil society.

While stimulating co-creation, the COVID-19 pandemic has also posed challenges to it, as lockdown measures, restrictions to mobility and social distancing rules reduced networking opportunities that are essential to new trusted research partnerships and collaborations. As a consequence, many co-creation projects were implemented among those who had already collaborated before. A more in-depth discussion on the impacts of COVID-19 on STI and policies adopted to support the activities of STI actors, including co-creation, is provided in Paunov and Planes-Satorra (2021^[31]) and Paunov and Planes-Satorra (2021^[32]).

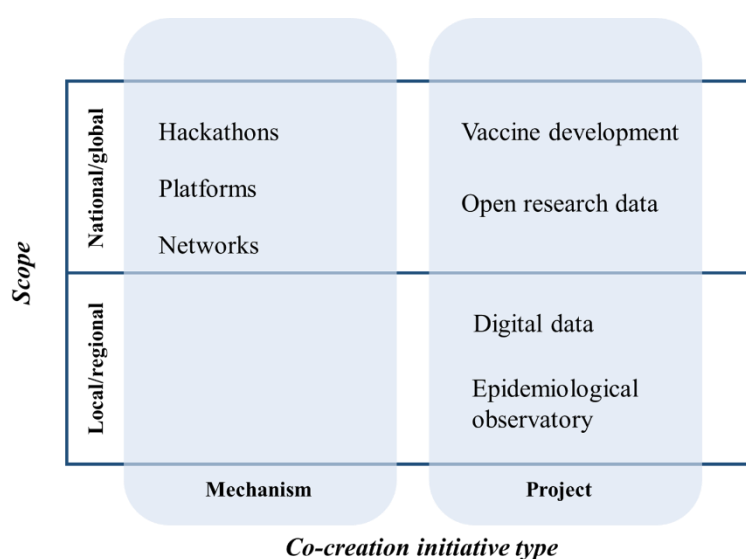
4.1. A diversity of COVID-19 co-creation initiatives

Co-creation initiatives have been particularly important during the COVID-19 pandemic to create the necessary institutional settings for knowledge co-creation to take place. Such initiatives can be classified

in two types: co-creation projects and co-creation mechanisms. Co-creation projects aim to address specific COVID-19-related challenges by engaging actors across industry, research institutions and civil society. They focused on vaccine development, the creation of open data repositories and the development of specific products, such as ventilators. Co-creation mechanisms provide the necessary infrastructure to connect experts, create ad-hoc teams and enable the mobilisation of different actors to address a range of COVID-19 challenges. Notable examples of such mechanisms are digital platforms and hackathons. While projects may focus on addressing challenges at local, regional, national or global levels, mechanisms tend to focus on addressing national or global challenges (Figure 4).

Figure 4. Differences in scope by initiative type

Examples of co-creation COVID-19 initiatives to illustrate the different focus of the two initiative types



Source: Developed by authors

Some COVID-19 co-creation initiatives provided short-term responses to the COVID-19 pandemic, while others are still ongoing or are emerging. An example of an ongoing joint effort is the creation of the [COVID-19 Open Research Dataset \(CORD-19\)](#) by the Allen Institute for AI, the National Library of Medicine, the Chan-Zuckerberg Initiative, Microsoft, and Georgetown University's Center for Security and Emerging Technology (CSET), at the request of the White House Office of Science and Technology Policy. By the end of September 2020, it contained over 200,000 machine-readable scholarly articles on COVID-19 and related coronaviruses, including over 100,000 with full-text (The White House, 2020^[33]). The dataset is updated in real time and continues to serve as a basis for applying machine-learning techniques to generate new insights to support COVID-19 research.

COVID-19 co-creation mechanisms have been set up by governments, universities and civil society actors (e.g. associations, individual scientists or researchers, firms). In particular, online platforms have become a popular mechanism to reach out to and virtually bring together different actors, in a context of limited possibilities to meet in person given the lockdown and social distancing measures implemented in large parts of the world. The focus of these platforms ranged from providing access to health technologies to collecting expertise, creating Open Innovation (OI) communities, gathering competences, fostering research that engages a diversity of actors, developing and sharing open source solutions and building citizen science projects.

Initiatives implemented by governments to support co-creation have also focused on the promotion of international collaboration and data sharing. In Canada, the [Pandemic Response Challenge Program](#) aimed to mobilise Canadian and international researchers from universities, business and government

to work together to address specific COVID-19 challenges identified by Canadian health experts (Government of Canada, 2020^[34]). A number of government calls also focused explicitly on promoting international collaboration and data sharing. For instance, in May 2020 the National Research Foundation (NRF) of Korea launched a [Rapid Call for International Joint Research against COVID-19](#), to conduct epidemiological research involving Korean researchers collaborating with researchers abroad. The National Natural Science Foundation of China (NSFC) and the Russian Foundation for Basic Research (RFBR) launched an [international call for collaborative COVID-19 research proposals](#) from teams comprising researchers from the People's Republic of China (hereafter "China") and the Russian Federation. Another example is the [Nordic Health Data Research Projects on COVID-19](#), a call to foster research co-operation and health data sharing across Sweden, Finland, Denmark, Norway, Iceland, Estonia and Latvia.

4.2. Societal engagement plays a key role in many COVID-19 co-creation initiatives

Civil society and its institutions (e.g. foundations and NGOs) have been actively involved in STI in the context of the COVID-19 crisis.

The active involvement of civil society has been an important aspect in most co-creation mechanisms (in particular in hackathons) and in some of the co-creation projects that have been created since the beginning of the COVID-19 pandemic. An example of the latter is the Flanders Totally Digital project ([‘Vlaanderen helemaal digital’](#)) which mobilised professional federations, civil society organisations and governments in the Flanders region (Belgium) in response to the first wave of the COVID-19 pandemic. The project produced 400 solutions and resulted in 35 collaborations by summer 2020. This project also resulted in an online platform that brought together citizens and scientists. Another examples is [“CrowdVsCovid”](#) – an online platform created by a team of citizens and scientists from research institutions in France, Italy, Spain, Switzerland and the UK to provide policy makers with relevant and reliable information on COVID-19 challenges. In these challenges, an AI gathers preliminary data, which is then cleaned and supplemented by volunteer citizen and scientist reviews. For example, the AI identified images of people wearing masks and volunteers identified the types of masks worn.

Hackathons were another popular co-creation mechanism in the first wave of the pandemic in 2020. Organised by governments, non-profits, universities and supranational and international organisations, their objective was to draw ideas from diverse contributors. Hackathons are typically events with a duration of 24- to 48-hours in which participants are provided with data with which they have to create an innovative product. Winners are often compensated with funding to develop and scale up their ideas. A lighthouse example is the [EUvsVirus](#) initiative by the European Commission, which combined a hackathon on 24-26 April 2020 with a subsequent matchmaking event (‘Matchathon’) in May 2020. More than 2,100 multi-disciplinary international teams participated in the hackathon to address around 20 COVID-19 related challenges. The Matchathon that followed enabled the 117 winning solutions from the Hackathon to pitch their ideas to 458 partners including investors, corporates, public authorities, academia and research institutions from 40 countries. Civil society actors have also been able to participate in national hackathons such as [‘WirvsVirus’](#), a 48-hour virtual hackathon in March 2020 with 40,000 participants that worked on more than 800 projects on over 45 COVID-19-related themes in Germany.

Online platforms also enabled a large number of volunteer researchers and innovators to engage in frugal innovation efforts – which in this case refers to improvised production processes to address product shortcomings in the absence of sufficient production capacities to respond to global demand – to jointly develop solutions in the early phase of the pandemic. For instance, in Spain, [Coronavirismakers](#) was an open-source community founded in March 2020 by civil society that gathered more than 20,000 volunteer researchers, developers and engineers. With the support of firms,

public administration and foundations, by 15 May 2020 the group had produced more than 840,000 face shields and 123,000 hands-free door openers. Similar initiatives include [Helpful Engineering](#) and [Crowdfight COVID-19](#).

Foundations have played an important role in supporting STI in the COVID-19 context. They have been prominently involved in highlighting important COVID-19-related threats, including a number that require innovations to address them, and providing funding support for global solutions. For instance, the [COVID-19 Therapeutics Accelerator](#) (CTA) aims to accelerate the development and scaling-up of treatments for COVID-19 and was launched by the Bill and Melinda Gates Foundation, Wellcome and Mastercard, with an initial budget of USD 125 million.

In addition, companies have been contributing to the initiative by sharing their proprietary libraries of molecular compounds that already have some degree of safety and activity data to quickly screen them for potential use against COVID-19. The funding call ‘Corona Crisis and Beyond – Perspectives for Science, Scholarship and Society’ by the [Volkswagen Foundation](#) in May-June 2020 attracted 1,107 small grant applications. It focused on supporting individual or cooperative research projects that address COVID-19-related challenges by testing or developing new scientific approaches, methods or theories in the fields of life, natural, engineering and social sciences. In December 2020, 102 applications were selected and received funding up to 120 000 EUR for flexible use for up to 18 months. At the time of writing in May 2021 no additional updates had been released.

5. Typical challenges in co-creation initiatives

Co-creation initiatives face a number of obstacles to being successful: engaging all stakeholders including civil society, setting up effective governance and operational management, clarifying ownership and exploitation of collaborations and adapting to changes. The remainder of this section discusses these challenges – and potential solutions.

5.1. Engage stakeholders

A key challenge of co-creation initiatives is to build operational partnerships with clearly defined shared goals among their various stakeholders. Successful co-creation initiatives need to offer incentives for the actors involved and to clarify from the outset how each will contribute to and benefit from the initiative. In the absence of clear incentives and well-aligned objectives, co-creation partners will not contribute as needed for successful co-creation. This includes specifying the benefits for industry partners and reconciling different views among involved civil society stakeholders (Grillitsch et al., 2019^[35]).

In addition to having shared project goals, setting shorter-term milestones helps a co-creation initiative succeed because it increases the visibility of progress made and helps maintain the momentum of those involved in the collaboration. It is also a good way to regularly review and, if necessary, adjust the direction of work to respond to unexpected results, be they unforeseen opportunities or challenges.

Moreover, creating personal relationships and trust is vital to ensure the lasting engagement of stakeholders. An example of how to achieve this was provided in the Triangulum project in Norway, which is about demonstrating and disseminating solutions and frameworks for Europe’s future smart cities. The initiative approached decision making in an equitable and democratic way. This was considered crucial for both cooperation and for partners’ motivation (Seehus, 2020^[14]). Creating trusted relationships can be more challenges if collaborations are virtual, such as exemplified in the Open Innovation Platform in Lombardia. The experience of the initiative showed that longer-term relationships beyond the scope of individual projects are often to build trusted connections for effective knowledge co-creation (Cristofaro and Martinelli, 2020^[11]).

There are multiple ways in which civil society can be involved in knowledge co-creation initiatives that address societal challenges:

- *Setting the specific objectives to be addressed.* An example of such efforts is Ruggedised, a European H2020-funded smart city project that operates in six European cities (2016-21), aiming at promoting more sustainable and resilient cities, notably by reducing the impact of economic activities and urban transport on the environment. The initiative works with multidisciplinary experts, citizens, industrial partners, city decision makers and knowledge centres to exchange on how to achieve this objective.
- *Engaging citizens in innovation.* The number of hackathons set out in the early phase of the COVID-19 crisis set up a co-creation context where citizens were asked to proposed innovations and then, if successful, were matched with entrepreneurs to implement their solutions. New digital platforms such as Zoouniverse, FoldIT and eBird, for example, engage thousands of citizens on a daily basis in rigorously designed scientific research projects (Dai, Shin and Smith, 2018^[4]).
- *Providing research inputs, such as data collection or supply.* This may involve using citizen-generated data to design the collaborative solution or involving citizens in games to help identify solutions. Ruggedised, a European H2020-funded smart city project that operates in six European cities (2016-21), builds on energy consumption data to create smart solutions to reduce consumption. Patient participation in co-developing treatments is another way of engaging citizens and can also involve co-designing experiments.
- *Evaluating, disseminating and diffusing co-creation initiatives' results.* Diffusion is an important and challenging step for innovation, particularly where they require major changes in behaviour as is, for instance, projects that aim to introduce eco-friendly mobility. Members of civil society can play an important role in convincing their peers to buy in to innovation for social good.

However, there are numerous challenges to effectively engaging civil society in co-creation initiatives.

First, initiatives have to find ways to engage civil society and receive quality contributions. This is not an easy endeavour, as engagement requires investing time outside of working hours. It can also be difficult to incentivise civil society participation, as rewards for civil society actors are often mainly in addressing the community challenge, rather than providing private rewards. This was the case in the project 'BrusSEau' on water management in Brussels. Residents became involved in living labs that focused on implementing tools for measuring hydrological flow in public and private spaces, or the design of new urban rivers in collaborative cartography workshops. One of the challenges it encountered was providing very detailed technical information to citizens. This was addressed by putting emphasis on diverse communication tools. This ensured clear internal project communication and visibility of results to external audiences, as well as awareness about the water management problems that the project addressed (Crespin, 2020^[6]).

Second, coordinating and prioritising the contributions of large numbers of participants in those activities involving a wide range of civil society actors is an important priority. For example, the Open Innovation Platform Lombardy has dedicated platform managers from an in-house agency that prioritises themes according to the policy framework of Lombardy region. This enables it to effectively coordinate the contributions from more than 20,000 registered participants (Cristofaro and Martinelli, 2020^[11]).

Third, effective engagement requires integrating diverse perspectives to avoid biases towards certain interest groups that may be more organised or more vocal in expressing their perspectives than others.

For instance, the design and set-up of new urban mobility solutions to reduce pollution will benefit from citizen involvement but views on the best way to organise transportation may diverge.

Digital tools can enable the engagement of civil society actors in co-creation initiatives, as has been the case during the COVID-19 crisis during which digital collaboration became more widespread as working-from-home became more common (Paunov and Planes-Satorra, 2021^[36]). Digital tools – such as web platforms for information exchange and collaboration but also surveys and social media sites – can facilitate engagement, provide ways to deal with many diverse contributions, and also be a means to address diverse actors. Recognising the importance of these tools, the open innovation platform of the region of Lombardia offers a tool to create technology challenges and contests to improve co-creation among small- and medium-sized enterprises, universities, students, researchers, and citizens.

5.2. Governance and operational management

There are several important steps to setting up the operations of co-creation initiatives. From the start, the roles and responsibilities of the different actors, the division of labour, and the financial and in-kind contributions to be made by each member need to be clearly set out. The kinds of tangible and intangible contributions of partners will differ, and these need to be clearly identified. Also, clear rules need to be set regarding user rights to the initiative's resources (including the technology, facilities, human resources and other assets such as databases).

Agreements or contracts that specify the governance structure, the role and expected contribution of each partner, as well as operational procedures and timelines, are necessary for co-creation initiatives. Contracts need to be simple and pragmatic. Particularly in the case of large consortia, it may be advisable to create a dedicated project manager position as well as a clear governance structure comprising a consortium management board and project steering group, as illustrated with the case of the RA-MAP consortium in the United Kingdom – a multi-partner university-industry partnership to advance genomic medicine in rheumatoid arthritis (Cope et al., 2018^[37]). Its consortium management board, co-chaired by industry and academia, is a small executive committee that coordinates activities and reports progress to the funders. The project steering group is made up of representatives of all consortium partners, meeting a few times per year to take broader strategic decisions.

A particular challenge is that the relationships between co-creation partners are often asymmetrical and hierarchical rather than completely reciprocal and balanced, which can lead to conflicts in the distribution of decision-making power and appropriation of the results.

Coordinating institutions can play an important role in building collaborations across multiple stakeholders. For example, the OneSea Ecosystem in Finland aims to create a technological and legislative environment that is suitable for autonomous ships by 2025. The rationale of the ecosystem is to operate as an enabling platform for ecosystem participants by removing legislative barriers and prejudices against the introduction of autonomous vehicles and creating collaborative projects related to autonomous maritime transport system. The case study points to the important role of the orchestrator company DIMECC (Digital, Internet, Materials & Engineering Co-Creation), co-owned by 43 industrial and digital companies and 23 research institutes. It requires management skills to effectively bring together the variety of business ecosystem actors involved (Hyvärinen and Kotiranta, 2020^[8]).

Digital technologies can play a supporting role in the operational management of co-creation initiatives. In the case of the German Fraunhofer AHEAD programme, a deep tech entrepreneurship platform, the continuous monitoring of all co-creation projects is made possible by a data-enabled platform (Schimke, Lambertus and Schmalenberg, 2020^[10]). Similarly, the China-ASEAN Technology Transfer Center (CATTC) operates an information platform to manage the supply and demand of technology transfer projects, disseminate information on conferences on events and provide support services to co-creation initiatives. CATTC is the only ASEAN-oriented technology transfer agency on a national level in China and is devoted to forging the China-ASEAN Technology Transfer Cluster Area by integrating

technology transfer, joint research, S&T exhibition, incubation, and technology training as a whole (Zhou, 2020^[7]).

Finally, monitoring and evaluation must be part of effective project management to ensure that actions do not deviate from initial project objectives, while allowing for some flexibility to adapt the objectives when necessary. Project reviews also benefit from adopting transparent, robust and independent methods for evaluating project success.

5.3. Ownership and exploitation of jointly developed data and intellectual property

Reaching an agreement on the ownership of data and intellectual property (IP) can be a major challenge in co-creation initiatives. Industry partners expect rewards from their engagement in collaborative research, which may take the form of privileged access to the data and jointly created IP. Co-funding from the public sector, however, requires a commitment to ensuring that these collaborations create benefits beyond the firms involved. Take the example of the co-creation case study from the Russian Federation. The joint laboratories at the Higher School of Economics highlight a new kind of value that results from co-creation activities which are the algorithms that were created to tackle specific companies' questions but that are of value that extends beyond this narrow application on proprietary data and can serve scientific or educational purposes at the university (Meissner, 2020^[16]). Another example of joint labs are the Laboratoire Commun (LabCom) in France. This annual programme, in place since 2013, supports the establishment of joint labs between universities/PRIs and firms, with a particular focus on SMEs.

Therefore, guidelines regarding the ownership and management of data and intellectual property are essential. These need to anticipate potential conflicts and be developed considering the variety of stakeholders and different contributions of each member. Since setting up contracts that satisfy all parties involved can be a cumbersome process, the provision of model contracts by IP offices can help potential projects become a reality. Diverse approaches have been adopted and range from providing business partners with full IP rights to making the results of collaborations available to the public, or owning the IP and licensing it to external partners. The latter is the case in the Fraunhofer AHEAD program, in which Fraunhofer funds the IP creation and thus owns the IP which is then licensed to external partners (Schimke, Lambertus and Schmalenberg, 2020^[10]).

5.4. Adapting to a changing the organisational environment

Co-creation initiatives may unfold iteratively and thus do not necessarily follow a linear pathway, being subject to changes in their organisational environment. For example, the priorities of business partners may change, making it necessary to react flexibly to these changes. This requires the ability to redefine their role based on the changing demands and requirements of partners. Intermediaries such as brokers also need to respond flexibly to the changing priorities of business partners and be able to redefine their roles in light of a changing organisational environment (Rossi et al., 2020^[18]).

The ability to adapt to changing environments has been identified as a key factor at the joint laboratories of the Higher School of Economics in Russia, which were founded in cooperation with a digital company and a bank. Both are subject to business dynamics which require flexibility from the side of researcher collaborators to respond to the changing requirements and priorities of the business partner (Meissner, 2020^[16]). bcom Institute of Technology in France, an independent innovation centre that aims at supporting firms' use of digital technology, has created a small board of directors for agility and fast decision-making. It is composed of similar numbers of members from industry and academia, as well as a staff representative (Guilbaud, 2020^[9]).

6. Policy implications

This section discusses policy implications and concrete action points regarding knowledge co-creation that emerged from the conceptual and empirical analysis presented in this paper. Creating successful co-creation initiatives requires careful consideration of strategic and operational aspects. It consists of at least four steps which are summarised in these policy questions:

1. Why and how should STI policy support co-creation?
2. What framework conditions are important for the success of co-creation initiatives?
3. What design choices are critical to co-creation initiatives?
4. What should be considered when managing a co-creation initiative?

6.1. Rationale for and ways in which STI policy can support co-creation

Several policy rationales justify support for co-creation initiatives. These are closely linked with the strengths of co-creation. First and foremost, co-creation can provide for more effective industry-science collaborations and in this way can boost innovation. By engaging civil society, co-creation democratises innovation and is an important means of innovating to achieve major societal goals, such as environmental sustainability. Public support in the early stages can be essential, as set-up and coordination costs may be too high for individual actors to bear.

Co-funding with private actors is a privileged mode of support. To engage stakeholders throughout a co-creation initiative, all actors have to have a stake in its outcomes. Hence, policies need to balance between risk and reward when setting individual contributions to ensure a sense of ownership while remaining feasible for all actors to participate in. These contributions could consist of financial contributions and active in-kind investments by all actors involved. Several co-creation initiatives are funded in this way. For example, in the Portuguese Collaborative Laboratories (CoLabs) and the Austrian CDG Laboratories, each project requires a minimum of 50% co-funding by industry. In the Irish SFI Research Centres, a minimum of 30% of the budget of each centre must be secured from industry. In the United States' IUCRC programme, each centre is expected to collect at least USD 400,000 annually through membership fees from at least eight industrial partners. In the case of the Dutch "top consortia for knowledge and innovation" (TKIs), for every euro that industry invests in a research partnership with a university or research institute, an additional allowance of 25 cents of public funding is provided. In the Australian CDG Laboratories and the German Research Campuses, the partners (universities and firms) must match the grant received, but there is no indication of a minimum share to be funded by industry. In the Spanish CIEN programme, consortia of 3-8 companies including at least one SME need to subcontract at least 15% of the budget of the project to a public research organisation.

Effective integration of co-creation initiatives across funding programmes. Co-creation can be integrated as part of wider funding support by including explicit targets and funding criteria that foster co-creation in funding instruments, such as metrics that reflect networking-building or the mobilisation of actors to jointly create knowledge. Growth Engine, a funding instrument of Business Finland, includes concrete co-creation metrics such as network creation, rather than just academic excellence or economic success.

Co-creation initiatives that focus on national priorities have a higher chance of success. Favourable legislation and framework conditions can boost the success of co-creation initiatives and vice versa they can drive progress in areas of public interest and national priority. Many co-creation initiatives set out to develop a solution to an issue that is of general public interest, such as environmental sustainability or inclusiveness. Examples from the TIP project's co-creation case studies (see

Table 1) include fine dust pollution in Korea and GHG emissions and the quality of life in cities. The former is a pan-ministerial project group that functions as an implementation platform of the pan-ministerial joint initiative on fine dust by the South Korean government (Sohn et al., 2020^[13]). The latter example focuses on the city of Stavanger in Norway in the EU H2020 Triangulum project that sets out to enhance quality of life by delivering efficient and clean mobility to residents (Seehus, 2020^[14]).

International co-creation initiatives can be efficient means to address innovation challenge that require international collaboration. Global societal challenges such as climate change or pandemic response are a case in point. Co-creation initiatives such as Future Earth, an international network of scientists and innovators to accelerate transformations to global sustainability through research and innovation, or the Green Economy Coalition, a public-private partnership with over 50 members from different countries working towards transitioning to a green economy, illustrate the strong potential of large international partnerships involving multilateral organisations, national governments and firms to address grand societal challenges. Another example are Chile's International Centres of Excellence in R&D that consist of a research centre (from a university, public research institute or firm) outside of Chile that forms a partnership with Chilean universities and firms. The programme aims to promote science-industry collaboration and to access foreign technology in strategic industries for the Chilean economy.

Local co-creation initiatives can be effective ways of engaging civil society and can be a means of achieving inclusive and sustainable development. Co-creation initiatives to address local issues make it possible to bring together local actors from companies, universities, research centres as well as public and private agencies to respond to a specific challenge that directly affects civil society actors. The resulting collaborative activities foster inclusivity in innovation processes. In research and innovation for sustainable development, key technological milestones require research and industry to work together, and citizens to give direction. This was the case in the Triangulum project in the city of Stavanger in Norway. One of the project work streams aimed at enhancing the quality of life in cities by delivering efficient and clean mobility to residents. To do so, they ran a competition on the design of e-buses at local high schools. Out of over 100 submissions, a jury selected 7 designs which were voted on by 22,000 citizens (17% of all citizens in the city) in a local newspaper. When unveiling the actual buses in a public ceremony, the project raised awareness on carbon emissions, energy savings, and other positive impacts of solutions that had been implemented thanks to the project (Seehus, 2020^[14]).

6.2. Framework conditions for successful co-creation initiatives

This section considers framework conditions that are essential for the success of co-creation initiatives; namely, favourable conditions in strategic areas of public interest, flexible labour policies and whole-of-government approaches.

Favourable conditions in strategic areas of public interest. Legislation that supports certain practices and creates a positive climate is an important indirect driver of co-creation initiatives in related fields. Multiple levels of regulation at the national, transnational and product levels can challenge the optimal use of research funds and build capacity to participate in international scientific and technological innovation cooperation. A recent example of legislation that fosters such practices is Korea's fight against fine dust air pollution, for which it not only created a pan-ministerial joint co-creation initiative with a pan-ministerial project group, but also enacted the Special Act on Fine Dust Reduction and Management in August 2018 as well as the Master Plan for Fine Dust Management in October 2019 to facilitate R&D and active communication among key stakeholders (Sohn et al., 2020^[13]). With regards to selecting areas of public interest, Sweden's SIP programme provides an interesting model based on wide consultative processes with different stakeholders that jointly formulate roadmaps and innovation agendas in each field. In the case of the Netherlands, TKIs have been established within each of the nine designated "top sectors", which reflect the country's strategic industries and technologies. In contrast, the Austrian CDG Laboratories programme focuses on basic research of relevance to industry but does not explicit set thematic priorities.

Flexible labour contracts that allow for temporary staff mobility. Such policies enable staff from universities and companies to move to other institution for a defined period of time to become involved in co-creation initiatives. They are just as important in co-creation as in knowledge transfer in general and are vital for attracting highly skilled individuals to co-creation initiatives. Co-creation policies adhere to the national labour policies of the country that they have been created in. This was raised as a key obstacle by the co-creation case studies from France and the Russian Federation. The latter also pointed to the issue of attracting young experts and retaining a team on a long-term basis (Meissner, 2020^[16]). The attraction and retention of staff to these initiatives should be a key concern for national labour policies.

Whole-of-government approaches to fostering regulation that concerns co-creation initiatives. Dialogue between multiple levels of regulation on the national, transnational and product levels can overcome many challenges that co-creation initiatives typically face. Good practice is the establishment of pan-ministerial groups, such as in Korea's fight against fine dust (Sohn et al., 2020^[13]). For co-creation initiatives that aim at international collaboration, this is particularly important as approaches that act across different ministries and coordinate with counterparts in other countries may result in tangible positive effects, such as easing procedures and restrictions on overseas use of research funds, building capacity to participate in international scientific and technological innovation cooperation and opening up national science and technology programmes. There are a wide range of examples of co-creation initiatives with an international scope. For example, in the German Research Campuses and the US' IUCRCs, various foreign firms have joined as industry partners, while some of the centres have also forged partnerships with foreign universities or research institutes. In the Austrian CDG Laboratories programme, the industrial partner may be a foreign company, including some without Austrian subsidiaries. The most intense international cooperation model can be found in the case of the International Centres of Excellence programme in Chile, where each of the 16 centres is formed through the attraction of a foreign research centre (from a foreign university, public research institute or firm), which then needs to forge partnerships with Chilean universities and firms. The programme fostered 21 collaborative R&D projects in the period 2015-2025. The China-ASEAN Technology Transfer Center (CATTC) is another case in point, established as it was under the framework of the China-ASEAN Science and Technology Partnership Program (Zhou, 2020^[7]).

6.3. Critical design choices for co-creation initiatives

After the decision in favour of creating a co-creation initiative and the analysis of framework conditions, the next stage is to design the initiative. These choices are relevant for public policy to consider as they affect the outcome of co-creation initiatives but also involve choices made by the partners – including industry and civil society. To do so, the analysis of co-creation initiatives showed that these considerations are important:

- Select the type of co-creation initiative – project, institution or mechanism – based on the issue that it sets out to address.
- Decide whether to involve an intermediary institution to independently orchestrate or facilitate co-creation activities.
- Creating dedicated spaces for co-creation.
- Adopt a democratic, flexible and operational governance model with management guidelines.

The type of co-creation initiative has implications for the resulting activities and impacts of the initiative. There are three forms of initiatives with advantages and drawbacks, and selection depends on the issue that it sets out to address: projects, mechanisms or institutions. A co-creation project has a rather narrow scope and is set up for a defined period of time, whereas a co-creation mechanism sets out to create the necessary institutional structures and settings in a specific context for knowledge co-

creation to take place. For example, co-creation mechanisms in the context of the COVID-19 pandemic have had different aims: hackathons to generate ideas, networks to connect experts and create ad-hoc teams as well as different kinds of online platforms to enable the mobilisation of different actors. Regarding co-creation projects, examples are the Triangulum project of the Lighthouse City Stavanger (Seehus, 2020^[14]) or the project BrusSEau on water management in Brussels (Crespin, 2020^[6]), both of which had a set timeframe from the beginning which their funding was tied to. In the context of the COVID-19 pandemic, the Flanders Totally Digital project ('Vlaanderen heeemaal digital') mobilised professional federations, civil society organizations and governments in the Flanders region of Belgium to think of solutions and cooperate during the lockdown in Spring 2020 and the project Breath4U that was implemented in Italy shortly after the outbreak of the COVID-19 pandemic to build a simple and affordable mechanical ventilator.

Involving intermediary institutions can be useful in specific co-creation settings. An intermediary institution can be important to orchestrate or facilitate co-creation activities. This is important in situations where co-creation activities are starting from scratch, or when coordinating actors in large-scale initiatives (Rossi et al., 2020^[18]).

There are a wide range of different types of intermediary institutions, ranging from innovation agencies to TTOs (see Box 2). In any event, it is vital that these institutions are neutral and impartial actors who act in the interest of all actors. Their legitimacy can originate from a clear mandate by a public agency with authority to perform their activities. For example, the French public policy to enhance the competitiveness of territories in specific technologies requires that all actors' interests are respected, and that the intellectual property of their weakest actors is protected (see Rossi et al (2020^[18]) for more information). It is important to bear in mind that these institutions take time to gain reputation, trust and a good understanding of the competencies in the respective regions and sectors. This means that it is important to ensure their survival with public funding even in difficult economic times.

Creating spaces suitable for knowledge co-creation can enhance the success of initiatives. Spaces may range from physical facilities such as joint laboratories, to virtual spaces such as digital platforms, to a combination of both. These different kinds of co-creation spaces may be combined under one roof, leading to hybrid spaces for co-creation that may include a traditional incubator within a science park, perhaps in the vicinity of a university with a living lab, all of which can be connected with other digital platforms (Box 3). In the context of the COVID-19 pandemic, governments used mechanisms like online hackathons and innovation challenges to mobilise different societal actors to gather ideas and develop solutions to a wide range of issues. Some required domain expertise and equipment, like prototyping facilities, whereas others resulted in the compilation of interdisciplinary and mixed teams which included citizens, researchers and industry actors.

An effective operational governance model for each co-creation initiative is needed. Agreements or contracts that specify clear and transparent governance structures, the roles and expected contribution of each partner, as well as the operational procedures and timelines are essential to ensure the success of a co-creation initiative. A good practice is the establishment and exchange of management guidelines and training aimed at improving the managerial structures of co-creation initiatives. For example, in the United States the IUCRC programme supports the centres' management by offering systematic training for researchers presenting proposals and for prospective centre directors, as well as detailed instructions and facilitation (e.g. manuals on how to set up a centre, guidelines and standardised processes, model contracts for intellectual property, etc.). In Australia, an association of the [Cooperative Research Centres](#) has been set up to exchange best practices between research centres, among other activities. Co-creation initiatives should also have agile processes and allow for flexibility to accommodate dynamic evolution processes in order to respond to the typical challenge of changing institutional environments (see section 5.4). Several case studies highlighted the changing roles and involvement of co-creation actors over the course of the co-creation project timeframe. For example, the OneSea maritime business ecosystem adopts a flexible and bottom-up styles of working, which allows ecosystem members to join and leave

the ecosystem as they wish (Hyvärinen and Kotiranta, 2020^[8]). This means that the funding model and evaluation processes need to adapt to the circumstances and dynamic nature of the co-creation initiative.

Box 2. Towards a new generation of innovation agencies and intermediaries

As a result of changes in policy strategies in favour of co-creation approaches, innovation agencies and intermediaries are shifting from their traditional focus on supporting knowledge exchange towards building dynamic innovation ecosystems and creating new spaces for co-creation. In particular, technology transfer offices (TTOs) are increasingly adopting more active and systemic organisational roles in response to the influence of different stakeholders (Kreiling et al., 2019^[38]).

Beyond TTOs, new types of agencies and intermediaries are emerging to support co-creation. A relevant example is the Catapult programme in the UK, launched in 2015 by Innovate UK. The Catapult centres bring together businesses, entrepreneurs, scientists and engineers to work on late-stage R&D in strategic fields using innovative approaches. For instance, Digital Catapult, one of the 10 Catapults established to date, organises pit-stop events that bring together large firms, start-ups, SMEs and academics to jointly solve specific technology challenges. Disruptive technology start-ups and other actors that can contribute to solving specific challenges are identified via open online calls.

Another illustrative example is the Knowledge and Innovation Communities (KICs) supported by the European Institute of Innovation and Technology (EIT). KICs constitute a new policy instrument at the EU level, searching for more intense transnational science-industry collaborative platforms to foster entrepreneurship and innovation. There are currently eight KICs and each focuses on a different societal challenge. As opposed to traditional instruments, such as the funding of pan-European research consortia under the Framework Programmes, the KICs are articulated through a network of Co-location Centres (CLCs) established by each KIC to work “on the ground”.

The government may also drive the creation of an intermediary by developing new digital platforms to facilitate co-creation and community-based participatory research. A case in point is [Citizenscience.gov](https://citizenscience.gov/), an initiative designed by the US Government to accelerate the use of crowdsourcing to engage the public in addressing social needs and to accelerate innovation. The website also provides a Crowdsourcing and Citizen Science Toolkit that shows how to plan, design and carry out a crowdsourcing or citizen science project, and showcases a number of case studies.

Sources: (Leceta and Könnölä, 2019^[39]) ; (Digital Catapult, 2019^[40])

Box 3. Other typical co-creation facilities: living labs and hybrid co-creation spaces

Besides joint research centres and digital platforms, other co-creation facilities include science parks, incubators, accelerators and – more recently – living labs. Living labs are “user-centred, open innovation ecosystems, integrating research and innovation processes in real life communities and settings”. They are localised areas of experimentation within urban environments, in which stakeholders collaboratively develop new technology-enabled solutions. For example, Synchronicity (<https://synchronicity-iot.eu/>) living lab projects gather experts and businesses that, in alliance with local governments, implement pilot programmes that address specific societal challenges through an Internet of Things (IoT) solution.

These developments suggest that digital platforms often do not replace but complement human interactions: physical spaces and intermediaries have remained critical to date. This, however, may be changing with the wider development of digital communication tools and spaces.

Source: ENoLL (European Network of Living Labs) <https://enoll.org/about-us/> (accessed on 25 October 2019), (Paunov et al., 2019^[41])

6.4. Important considerations when managing a co-creation initiative

Managerial considerations are important for co-creation initiatives’ success or failure. The following recommendations followed from the case studies:

Conduct regular evaluations to inform decision making. Co-creation dynamics can result in changes to the initiative; it is therefore important that insights from regular evaluation processes inform decision-makers. This will also lead to the improved effectiveness of the co-creation initiative. Funders of co-creation initiatives could tie their contributions to the insights of regular reviews. Striking a balance between regular assessments that spur effectiveness and efficiency but that do not discourage participants from engaging in future activities is important. Good practice is the development and monitoring of a reasonable number of key performance indicators (KPIs). For example, the Fraunhofer deep tech entrepreneurship platform AHEAD has set progress on venture readiness as a core KPI which is assessed regularly and formally at three major milestones in the programme (Schimke, Lambertus and Schmalenberg, 2020^[10]). Other co-creation initiatives, like the SFI Klima 2050 centre, see KPIs as a tool to promote their vision and to ensure that their activities progress in the right direction. Its KPIs act as performance management for the Centre Board and measure relevant partner benefits and partner involvement. The KPIs go beyond those reported to the Research Council of Norway and are applied for one year at a time. The formal preparation for evaluation exercises is important, as it allows for substantiated impact assessment of outcomes as well as visibility of the contributions of different actors (Time, 2020^[15]). Approaches should consider involving all actors of the co-creation initiative to hear all voices, for example in ‘360-degree evaluations’.

Clearly set out data ownership rules for all actors. Before engaging in a co-creation initiative, all actors need to be clear on the rules around ownership and use of data resulting from the activities of the initiative. Good practice is asking for legal support to form framework agreements that secure the interests of all partners involved. At AITeC, the AI Technology Consortium in Japan, for example, data is freely shared among members, except in specific cases in which non-disclosure agreements (NDAs) are signed by relevant members (Kawano, 2020^[12]). Good practice is the use of legal support to form framework agreements that secure the interests of all partners involved. This was the case in the Triangulum project (Seehus, 2020^[14]). In the SFI Klima project, the partners signed a legal agreement

in which each partner had ownership rights to the results that they themselves produced. Joint ownership was only the case where several partners produced a result in a collaborative effort, and where their respective shares of the work could not be ascertained (Time, 2020_[15]).

Select co-creation actors in a considerate and transparent way. It is important to clearly identify the kinds of actors that are to become involved in the co-creation initiative. Their scope can vary from science-industry-research partnerships that involve large consortia with over ten companies to bilateral partnerships between one company and one university or research institute. Selection criteria for partners could be their potential to generate value and scale up as well as the degree of relational proximity based on pre-existing interactions, as it was pointed out in the Wildlabs TechHub initiative (De Silva and Maxwell, 2020_[17]). Some co-creation initiatives solely target SMEs. This is the case with the French Laboratoire Commun (LabCom) programme, which only funds partnerships established by an SME and a university or public research institute. In the case of the German Research Campus initiative, SMEs need to be included in the consortia, but large firms continue to play a leading role. Similarly, a consortium of 3-8 companies needs to be formed to participate in the CIEN programme in Spain, among which at least one needs to be an SME, and at least 15% of the budget needs to be subcontracted to a public research organisation. The Australian Cooperative Research Centres (CRC) programme does not impose a specific quota, but it states that every centre must “implement strategies that build the R&D capacity within SMEs”.

Adopt collaborative practices from the start. In some co-creation initiatives, for example those that require an application process for funding, collaborative practices can be implemented from the very start of the process and enhance in this way effective collaborations. This makes it possible to create relational capital even before the official beginning of the co-creation initiative. Examples where this was done include the Triangulum project with the “Lighthouse City” Stavanger. The main partners held three joint workshops in Stavanger and Eindhoven to co-create the common parts and joint objectives of the application which was submitted by the project coordinator to the European Commission for funding, on behalf of all partners (Seehus, 2020_[14]).

Establish effective communication channels. Co-creation actors need to be able to communicate effectively during the co-creation initiative. Frequent interactions and communication between partners was highlighted as a success criterion in the co-creation case studies from the United Kingdom and the Russian Federation (see Table 1). Good communication is particularly important if stakeholders are in different locations. Digital platforms have been an effective way to enable this. For example, the co-creation initiative in Korea to fight fine dust established a dedicated platform to help facilitate active communication among citizens and other key stakeholders from local governments, public agencies, universities, and businesses so that they can jointly identify issues, present suggestions for improvement of the relevant laws and regulations, and propose policies and projects (Sohn et al., 2020_[13]). Similarly, the Open Innovation Platform of the Lombardy Region is a communication platform in itself which allows local companies or other relevant actors to gain visibility and accountability (Cristofaro and Martinelli, 2020_[11]). It is also important to plan early for the dissemination of results to audiences outside the co-creation initiative. This helps to build buy-in and anchor the results with future users or customers of the developed solutions, which results in future impacts. This was the case in both co-creation case studies from Norway. In the Triangulum project, various events such as public forums and cinema screenings were held to share the outcomes of the project’s co-creation activities with the broader community in the city of Stavanger (Seehus, 2020_[14]).

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