Science, Technology and Innovation (STI) for SDGs Roadmaps

BACKGROUND PAPER:
International STI collaboration and investment for Sustainable Development Goals

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Abbreviations and acronyms

AAAA	Addis Ababa Action Agenda
AIIP	AISTDF Innovation Platform
AISTDF	ASEAN-India S&T Development Fund
AIWGST	ASEAN-India S&T Working Group
ACE	(WB) Africa Centers of Excellence
ASEAN	Association of Southeast Asian Nations
ASEAN COST	ASEAN Committee on S&T
APASTI	ASEAN Plan of Action on Science, Technology and Innovation
AOSP	African Open Science Platform
ADB or AsDB	Asian Development Bank
ADF	(US) African Development Foundation
AFESD	Arab Fund for Economic and Social Development
AFD	French Development Agency
AMR	Antimicrobial Resistance
BEIS	(UK) Department for Business, Energy and Industrial Strategy
BDS	business development service
BMBF	German Federal Ministry of Education and Research
BMEL	German Federal Ministry for Food and Agriculture
BMG	German federal Ministry of Health
BMZ	German Federal Ministry of Economic Cooperation and Development
BMEL	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMWi	German Federal Ministry for Economic Affairs and Energy
BTCA	Better Than Cash Alliance
CEPI	Coalition for Epidemic Preparedness Innovations
CGIAR	Consultative Group on International Agricultural Research
COFOG	Classification of the Functions of Government
CO_2	carbon dioxide
CP	Contracting Party
CPRs	Common-pool resources
CSOs	Civil society organizations
CRS	Creditor Reporting System
CSTD	Commission on Science and Technology for Development
CSTP	(OECD) Committee for Scientific and Technological Policy
DAC	(OECD) Development Assistance Committee
DAI	Digital Africa Initiative
DB	Deutsche Bank
DEFRA	(UK) Department for Environment, Food & Rural Affairs
DEP	(OECD) Committee on Digital Economy Policy

DESA	(UN) Department of Economic and Social Affairs
DE4A	(WB) Digital Economy for Africa
DFID	(UK) Department for International Development
DH	(UK) Department of Health and Social Care
DIDA	(UK) Digital Innovation for Development in Africa
DOE	(US) Department of Energy or (UK) Department for Education
DoS	(US) Department of States
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DST	(India) Department of S&T
DZIF	German Center for Infection Research
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EFPIA	European Federation of Pharmaceutical Industries Associations
EPA	(US) Environmental Protection Agency
ERA, ERA-NETs	European Research Area, European Research Area Networks
EU	European Union
EUR	Euro
ExCo	Executive committee
FFO	(German) Federal Foreign Office
FtF	(US) Feed the Future
GAFSP	Global Agriculture and Food Security Program
GBP	Pound sterling
GCRF	(UK) Global Challenge Research Fund
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GFDRR	Global Facility for Disaster Reduction and Recovery
GIZ	(German) Corporation for International Cooperation GmbH
GNI	Gross National Income
GO-Spin	(UNESCO) Global Observatory of STI Policy Instruments
GPE	(German) Green People's Energy for Africa
GPGs	Global Public Goods
HHS	(US) Department of Health & Human Services
HLPF	(UN) High-Level Political Forum
IATF	Inter-Agency Task Force on Financing for Development
IATT	Inter-agency Task Team on Science, Technology and Innovation for the SDGs
IAVI	International AIDS Vaccine Initiative
IBRD	(WB) International Bank for Reconstruction and Development
ICs	(MI) Innovation Challenges
ICT	Information and Communication Technology
IDA	(WB) International Development Association
IDB	Inter-American Development Bank
IEA	International Energy Agency or Independent Evaluation Arrangement

IFAD	(UN) International Fund for Agricultural Development
IFC	(WBG) International Finance Corporation
IIASA	International Institute for Applied Systems Analysis
IKI	(German) International Climate Initiative
IMI	Innovative Medicines Initiative
IPCC	(UN) Intergovernmental Panel on Climate Change
IP	intellectual property
IPR	intellectual property rights
ISC	International Science Council
ISIC	International Standard Industrial Classification
ITFGPG	International Task Force on Global Public Goods
JICA	Japan International Cooperation Agency
JPIs	(EU) Joint Programming Initiatives
MADE	(OECD) Working Party on Measurement and Analyses of the Digital Economy
MAFF	(Japanese) Ministry of Agriculture, Forestry and Fisheries
MB	Management Board
MEA	(India) Ministry of External Affairs
MESRI	(French) Ministry of Higher Education, Research and Innovation
MEST	(French) Ministry for the Ecological and Inclusive Transition
METI	(Japanese) Ministry of Economy, Trade and Industry
MEXT	(Japanese) Ministry of Education, Culture, Sports, Science and Technology
MHLW	(Japanese) Ministry of Health, Labour and Welfare
MI	Mission Innovation
MIC	(Japanese) Ministry of Internal Affairs and Communication
MJIIT	Malaysia-Japan International Institute of Technology
MNEs	Multinational enterprises
MOE	(Japanese) Ministry of Environment
MOF	(Japanese) Ministry of Finance
MOFA	(Japanese) Ministry of Foreign Affairs
MSP	Multi-stakeholder platform
M&E	Monitoring and Evaluation
NESTI	(OECD) Working Party of National Experts on Science and Technology Indicators
NIS	National Innovation Systems
NLP	Natural Language Processing
NVA	(WEF) New Vision for Agriculture
OA	Operating agent
OECD	Organisation for Economic Co-operation and Development
ODA	Official Development Assistance
ODF	Official Development Finance
OOF	Other Official Flows
PASET	(WB) Partnership for skills in Applied Sciences, Engineering and Technology
PEPFAR	(US) President's Emergency Plan for AIDS Relief
PER	(WB) Public Expenditure Review

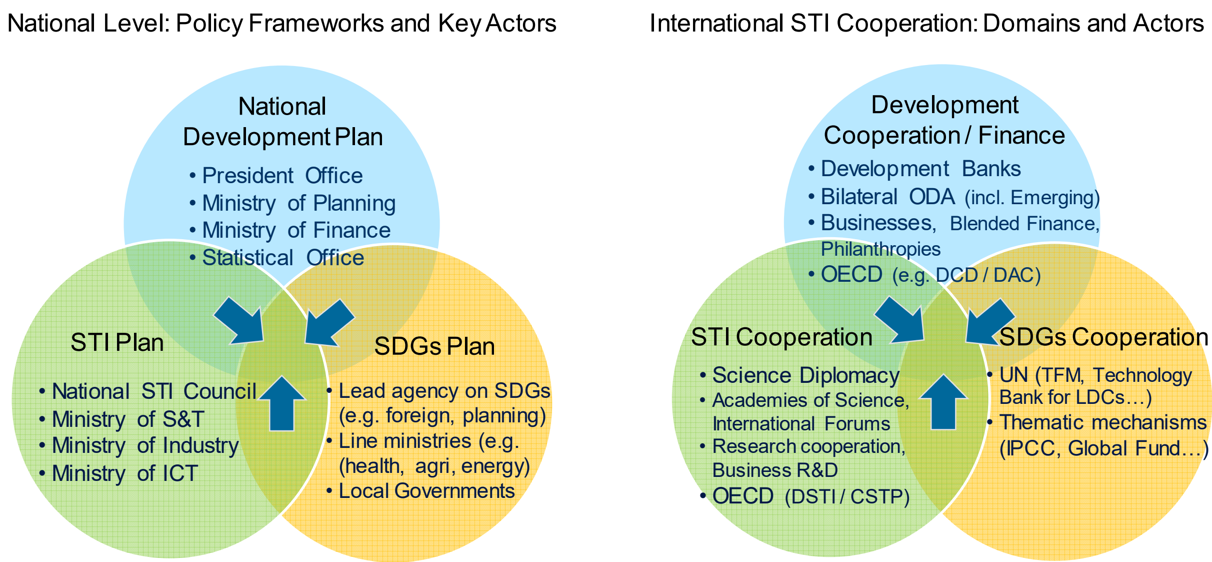
PPP	Public Private Partnership
R&D	Research and Development
RD&D	Research, development and demonstration
RTF	Research Training Fellowship
SMEs	Small and Medium Enterprises
SDGs	Sustainable Development Goals
Sida	Swedish International Development Cooperation Agency
SPDA	(German) Strategic Partnership Digital Africa
SRF	Strategy and Results Framework
STI	Science, Technology and Innovation
STIP Reviews	(UNCTAD) Science, Technology and Innovation Policy Reviews
STI Forum	(UN) A collaborative Multi-stakeholder Forum on Science, Technology and Innovation for the SDGs
STI for SDGs	Science, Technology and Innovation for Sustainable Development
S&T	Science and Technology
TCPs	Technology Collaboration Programmes
TFM	Technology Facilitation Mechanism
TICAD	Tokyo International Conference on African Development
TNA	(UNEP) Technology Needs Assessment
TOSSD	Total Official Support for Sustainable Development
UGEAP	(DB) Universal Green Energy Access Programme
UK	United Kingdom of Great Britain and Northern Ireland
UKRI	UK Research and Innovation
UN	United Nations
UNCTAD	UN Conference on Trade and Development
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFPA	United Nations Population Fund
UNICEF	United Nations Children's Fund
US	United States of America
USD	United States Dollar
USAID	US Agency for International Development
USDA	US Department of Agriculture
WEF	World Economic Forum
WHO	(UN) World Health Organization
WRG	(WEF) Water Resources Group
WB	World Bank
10-Member Group	(UN) a group of 10 high-level representatives from civil society, the private sector and the scientific community

Introduction

This background paper supports the United Nations (UN) Technology Facilitation Mechanism (TFM) and in particular, the UN IATT Guidebook on STI for SDGs Roadmaps (IATT 2019), specifically informing on its Chapter 3 on International Partnerships on STI for SDGs Roadmaps. Supporting the recommendations of the Guidebook, the paper overviews an increasingly complex landscape of international collaboration to harness STI to accelerate achievement of the SDGs and mitigate associated risks.

The Guidebook positions national STI for SDGs Roadmaps in the intersection of the three relevant policy domains, namely i) national development plans, ii) national STI plans and iii) national SDGs plans, encouraging governments' efforts for coherence and convergence through all-government and multi-stakeholder approaches. There is a parallel to these three domains at the international level, with distinct international actors and policy communities associated with each, and not necessarily working together closely (see Figure 0.1).

Figure 0.1. Key domains of international STI collaboration for sustainable development



Source: Authors based on (IATT, 2012)

In *development cooperation*, the call for the reinforced international STI collaboration should be seen in the wider context of the international commitments made in the Addis Ababa Action Agenda (AAAA)[1]. Governments committed to develop and adopt STI strategies and policies "that incentivise the creation of new technologies, that incentivise research and that support innovation in developing countries" (UN, 2015). Yet, four years after the AAAA, the Inter-Agency Task Force on Financing for Development (IATF) has found a lack of information on countries that have adopted policy frameworks for national STI strategies and how these fit into broader development strategies and that "developing countries need support from the international community to close technology gaps, address digital divides, keep up with rapid technology change and make progress towards the SDGs" (IATF-FD, 2019).

[1] AAAA highlighted the growing importance of STI to address global challenges and help bridge technological divides through additional investments in infrastructure, capacity building and knowledge sharing. For specific AAAA commitments related to STI, see Annex 1 of the Guidebook on STI for SDGs Roadmaps (IATT, 2019).

In *STI Co-operation*, the shared sense of purpose around addressing grand challenges, such as the SDGs including in developing countries, has emerged only recently (Colgazier, 2018). In *SDGs Cooperation* focusing on STI, as a result of formalization of Technology Facilitation Mechanism (TFM) in Agenda 2030, UN Inter-Agency Task Team (IATT) has been convening consultation forums such as the Annual Multi-stakeholder Forums on STI for SDGs, and its inter-sessional work including on STI for SDGs Roadmaps, to bring both STI and development policy communities together.

Accordingly, the Chapters 1, 2, and 3 of this paper summarize perspectives from policy communities on SDGs cooperation, development cooperation and STI cooperation respectively, as follows:

- Chapter 1 draws on literature and looks at three themes repeatedly discussed at UN STI Forums and particularly relevant for developing countries, namely, i) rapid technological change, ii) gaps in STI capabilities in developing countries and iii) the need to deliver Global Public Goods (GPGs).
- Chapter 2 overviews the current landscape of STI in development cooperation, focusing on bilateral and multilateral official development finance (ODF).
- Chapter 3 provides an overview of the STI policymakers' perspectives in international co-operation, focusing on key barriers, drivers and lessons for international STI collaborations addressing the SDGs.

Chapter 4 focuses on the intersection of the three and puts forward recommendations, on three models of international STI collaboration to address the SDGs: *Build* national STI capabilities, *Boost* international STI flows, and *Broker* global STI coalitions. Chapter 5 concludes the paper with summary findings.

1. Challenges and opportunities of international STI collaboration for the SDGs

The effective and widespread use of STI is key for delivering on the ambition of Agenda 2030 and for accomplishing the SDGs. The use of STI for SDGs needs to consider the global, interconnected, complex and uncertain nature of many global challenges. The SDGs cannot be met by any single country acting alone. They require unpresented collaborative efforts and investments from many countries and stakeholders working towards shared goals.

This chapter discusses the renewed rationale for international STI collaboration by highlighting three perspectives particularly relevant for developing countries, namely benefits and perils of rapid technological change for the achievement of the SDGs (1.1), gaps in STI capabilities in developing countries (1.2) and the need to collaborate to deliver Global Public Goods (GPGs) (1.3). The following sections outline these three perspectives.

1.1 Benefits and perils of rapid technological change for the achievement of the SDGs

Over the last decades, the world has been experiencing one of the fastest and disruptive technological change in modern history. Multiple innovations have been brought to market in areas spanning digital technologies, artificial intelligence, biotechnology and health technologies, advanced materials and nanotechnology, renewable energy technologies, satellites and drones or blockchain (UNCTAD, 2018a; 2019b). These new technologies, often coupled with and enabled by digital technologies, have created unquestionable benefits for society, economy and environment but they have also brought about new risks and uncertainties.

In its recent report for the UN Secretary-General, the Commission on Science and Technology for Development (CSTD) pointed to both potential benefits as well as risks linked to the recent scale and acceleration of technological change (UN CSTD, 2019). UN CSTD argues that rapid technological change can contribute to the faster achievement of the 2030 Agenda for Sustainable Development through e.g. improving income gained through increased productivity and reduced cost of goods and services; enabling faster and wider deployment of innovative solutions to economic, social and environmental obstacles that constrain development; supporting more inclusive forms of participation in social and economic life; replacing environmentally costly modes of production with more sustainable ones; as well as giving policymakers powerful tools to design and plan development interventions.

On the other hand, there are many areas of risk and uncertainty related to longer-term distributional impacts of technological transformation. The new technologies increasingly disrupt established production processes and business models across sectors, challenge public sector policies and institutions as well as change everyday lives around the world. They are creating pressure for many jobs, particularly those requiring lower-skilled workers (e.g. automation) but may soon substitute more sophisticated jobs (e.g. due to advances in AI). Using Industry 2.0 technologies to underpin industrial development and build competitive advantage is becoming increasingly challenging as new technologies require more mature ecosystems and capabilities (Hallward-Driemeier & Nayyar., 2017). The dual promise of productivity growth and job creation aligned with old forms of industrialisation becomes highly problematic as new technologies may allow high-income countries to keep manufacturing within their borders which will lead to loss of current jobs and future “potential jobs” in developing counties (ibid).

Frontier technologies may, therefore, exacerbate existing economic, social and technological divides within and between countries. Big data, IoT and other digital technologies could be harnessed by countries with strong innovation capabilities leaving others further behind (Hallward-Driemeier & Nayyar, 2017; UNCTAD, 2018ab). Sachs et al (2019) point to these risks and downsides as key for countries to identify and tackle in order to give a due consideration to the leave-no-one-behind principle of the Agenda 2030.

The proliferation of new technologies threatens to outpace the ability of societies, policy-makers and institutions and make it increasingly challenging to accept and adapt to the changes they create (UNCTAD, 2018ab). New digital technologies also create serious challenges for privacy (e.g. theft of digital identities, invasion of privacy by governments or businesses, discrimination based on personal data), governance (e.g. algorithmic transparency, monopoly positions due to control of big data, challenges to deliberative decision-making processes, hacking of election data and the manipulation of social media) and security (e.g. cyber warfare) (UNCTAD, 2018a; Sachs, Schmidt-Traub, Mazzucato, & Messner, 2019)

The bilateral and international STI collaboration is indispensable to tap in benefits of rapid technological change for the SDGs as well as to collectively anticipate, mitigate and adapt to the undesired effects of technologies on sustainable development. There is a need to include a dedicated critical reflection on the possible benefits and risks posed by disruptive technologies and new business models for the SDGs to the existing bilateral and multilateral collaborations as well as in the newly emerging initiatives. This is especially relevant for the least developed countries with the limited capacity to identify and manage potential social, economic and environmental risks emerging from deployment of new technologies.

Given the fast pace of technological development, a degree of risk and uncertainty surrounding future outcomes and wider impact of technological and non-technological innovations is inevitable. To create a common understanding and shared vision, the international STI collaborations could embrace foresight methods and tools allowing to develop a comprehensive understanding of STI opportunities and to systematically consider innovation scenarios and alternative technology pathways. Collaborative foresight should engage stakeholders and experts contributing diverse knowledge, including local knowledge, and ethical perspectives on new emerging technologies.

1.2 Gaps in STI capabilities in developing countries

The unprecedent progress and diffusion of information and communication technologies has contributed to the growth in productivity and the quality of life in many regions of the world. On the other hand, however, these changes have not equally benefited developed and developing countries and have exacerbated the growing inequalities within and between countries (UNCTAD, 2018ab). In order to benefit from the technological change, developing countries need to build systemic capabilities to select, absorb and diffuse knowledge and technology relevant for their challenges.

The absorptive capability of innovation system hinges on capabilities of various actors to engage in STI and build local and international collaborations as well as on the framework conditions in the innovation systems which create an enabling environment for learning and technology adoption. UNCTAD (2018, 2019a) differentiates between different roles and capabilities of actors in innovation systems:

- Firms and entrepreneurs: capabilities to learn, absorb, innovate and commercialize new knowledge and technologies with an innovative effect.
- Research and education system: capabilities to learn, absorb and develop new applied knowledge, and to supply human capital to the innovation system.
- Government: capabilities to mediate innovation priorities, support capabilities and connections in the innovation system.
- Consumers and users: capabilities to learn, test and adapt new technologies, altering practices to support or constrain systemic change
- Civil society and citizens: capabilities to challenge unsustainable practices, form alliances to lobby for change, mobilise and drive innovation, pioneering solutions.

The capability of firms and entrepreneurs to learn and absorb new knowledge and technologies, combine it with existing local knowledge and transform it into innovation is key for any effective innovation system. The capability to introduce innovations on the local, national as well as international markets is a prerequisite for technological upgrading and structural change and improving productive capacity of a country. Harnessing these capabilities to effectively address major societal challenges is crucial for accomplishing the SDGs irrespectively of where countries find themselves on their development paths.

Cicera & Maloney (2017) note that governments in developing countries are foregoing a massive opportunity by not investing enough in building absorptive capabilities of firms. They refer to this phenomenon a "innovation paradox" and call for a systemic approach to building innovation capacities differentiating between production, technology adoption and invention capabilities. Tapping into STI potential in developing countries should not be mainly about frontier science and technology but needs to give a due attention to improving basic capabilities which vast majority of SMEs and entrepreneurs in developing and emerging economies lack.

The capability of research actors to learn and apply knowledge to innovation processes is key for technological learning (UNCTAD, 2019a). Depending on their scientific and technological competences and capabilities, research actors can offer different knowledge and services to companies ranging from support to technology adoption (e.g. testing, certifications) to fully-fledged research and development (R&D), demonstration and experimentation processes. Bridging between research institutions and the contexts in which knowledge is used is key, especially in developing countries (Leach & Scoones, 2006). The broadly understood education system, including universities, technical vocational schools as well as governmental and non-governmental organizations providing training, can improve the quality of human capital available to firms, governments and research institutions. The education system needs to respond to the changing demand for specific skills to improve learning capabilities and absorptive capacity of firms and other actors, including disadvantaged groups. The universities need to revise their strategies and evaluation systems to reward research impacts and societal relevance not just research excellence.

The capability of government to negotiate and set up priorities, building capabilities and connections in the innovation system is key in formation of any innovation system. Policymakers can deploy a range of instruments to directly support innovation process and to tackle systemic failures inhibiting the performance of innovation system. They can ensure that the innovation system becomes more inclusive. A coherent STI policy mix is crucial to provide a stable and predictable environment for innovation in firms. Governments play a key role aligning the STI priorities of the national, regional and sectoral innovation systems with the challenges of sustainable development and the SDGs.

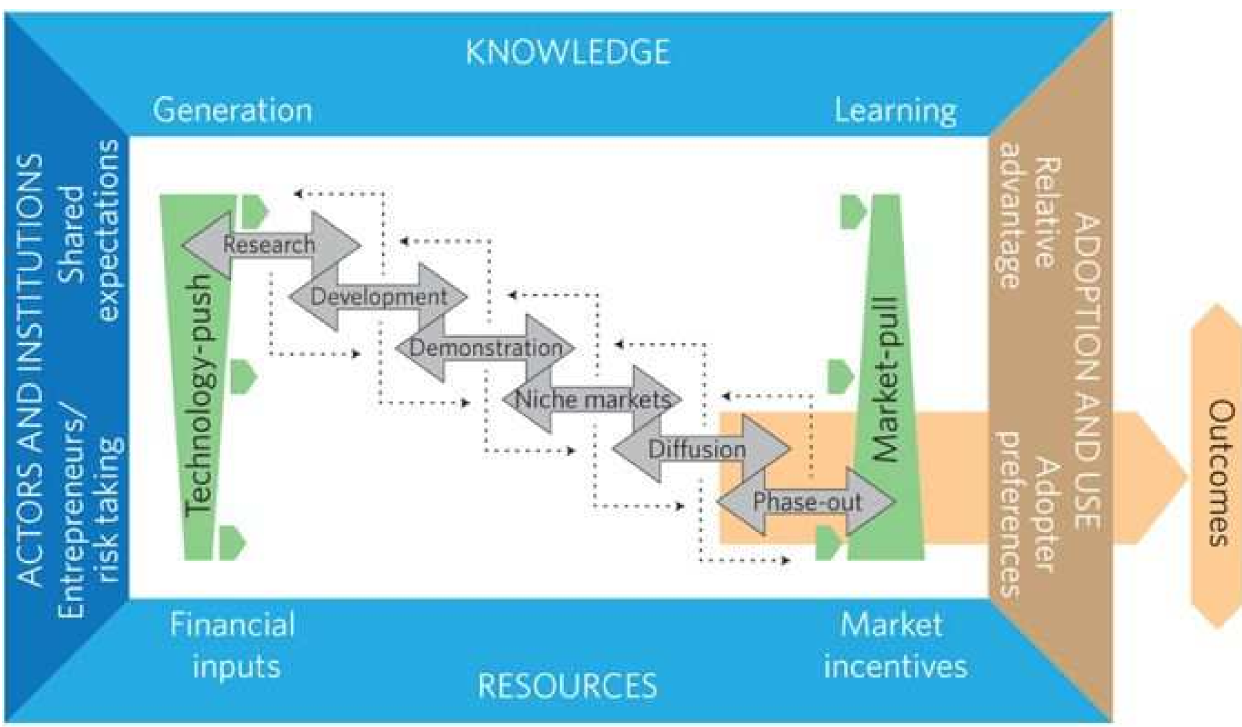
The capability of consumers and users has been increasingly recognised, both in terms of their ability to contribute to product innovations (von Hippel, 2005) and other types of innovations (Schot & Steinmueller, 2016). Users can be end-consumers, but also firms, and professional users. Active user involvement in innovation processes can lead to the design, adaptation and improvement of technologies, including frugal and low-cost technologies, and the emergence of open source digital collaboration (UNCTAD, 2017; 2019a). Users are important stakeholders in socio-technical system change and act to embed new technologies into their daily practices. Through shaping new routines, users are also created and build up niche markets for innovations. Indigenous communities often possess knowledge that is relevant to sustainable development which plays a role in some forms of grassroots innovation (UNCTAD, 2018a,2019a).

The capability of civil society and citizens are rarely considered key for innovation systems. The role of NGOs, social enterprises and engaged citizens is, however, crucial for developing as well as adopting and assimilating new technologies and promoting sustainable innovation. Civil society can assume a mediating role between technology developers and marginalized groups and promote innovations that consider social needs (Leach & Scoones, 2006; Leach et al., 2012; Smith & Stirling, 2018; UNCTAD, 2019a). In the context of developing countries, civil society can be instrumental in experimenting, testing, promoting and diffusing innovations designed to benefit the most disadvantaged regions and communities. Organised labour (trade unions) are important in the context of learning and adapting to new technologies to ensure social sustainability (UNCTAD 2019a).

Building absorptive capacity of local actors in developing countries will often rely on accessing foreign knowledge and technology (Metcalfe & Ramlogan, 2008; Cirera & Maloney, 2017; UNCTAD, 2019a). International flows of relevant knowledge can be enabled by different mechanisms, including public sector-led scientific and technology collaboration, public-private collaborations as well as private-led processes such as international trade, FDI, licensing or open access to scientific knowledge (e.g. Open Science movement). Technology transfer cannot be successful without a local absorptive capacity to absorb knowledge and innovate (Cohen & Levinthal, 1990). In this sense, technology transfer should not and cannot replace efforts to build up indigenous innovation potential (UNCTAD, 2019a).

Various STI actors play different roles in different phases of innovation processes or along "innovation chain" (see Figure 1.2). Actors need different capabilities to directly engage in or to benefit from basic and applied research, development, experimentation and demonstration, market formation, and diffusion of innovations relevant for accomplishing the SDGs. Phasing out socially and environmentally harmful technologies or infrastructures, which can be especially relevant for achieving the Global Goals, requires a dedicated attention in the process of transformation towards sustainable development. Innovation processes are often international and depend on the capabilities of actors to engage in international collaborations and finding ways to cooperate and compete in global value chains.

Figure 1.2. Innovation chain in the wider innovation system



Source: (Wilson, Grubler, Gallagher & Nemet, 2012)

The capabilities of STI systems to learn and innovate depend on the existing linkages between actors and wider framework conditions of innovation systems (Metcalfe & Ramlogan, 2008). Networking capabilities are key to enable learning, adoption of technology, collaborative innovation processes as well as the flows of resources, including finance, human capital and information (UNCTAD, 2019a). The key linkages are those between academia and industry (Cirera & Maloney, 2017), however, many innovations relevant in developing countries require collaborations between variety of stakeholders, including entrepreneurs, civil society and local communities.

The framework conditions enabling STI are multi-faceted and multi-level. UNCTAD (2019a) considers the following areas key building blocks of enabling environment of innovation:

- Regulatory and policy framework: Stable regulations and policies incentivise firms as to invest in research, technology and innovation (Chaminade, Lundvall, Vang, & Joseph, 2009; World Bank, 2010). Developing countries often suffer from insufficiently developed and fragmented policies. Improving regulatory and policy frameworks is an opportunity for developing countries to improve their STI systems.
- Institutional setting and governance: Institutional setting and governance include formal laws, standards and norms and informal social and cultural norms in a society, as well as the organizational settings and governance mechanisms used to create, regulate and enforce them. The wider notion of governance includes the role of new actors, including NGOs, citizens and grassroots movements, in advancing new forms of innovation (e.g. pro-poor innovation) (UNCTAD, 2019a)
- Entrepreneurial eco-system and access to finance: Organizational capabilities, formal and informal networks and institutional frameworks encouraging creativity and enabling entrepreneurs to engage in innovation process. Firms and entrepreneurs need to develop managerial competences to develop credible business plans and to assess risks of their projects. Access to finance is key for encouraging business incubation and growth of innovative companies.
- Human capital: Human capital allows to engage in technology adoption and innovation process, and to harness wider benefits of STI, including in poorest and most remote communities. Human capital relies on all levels of education and includes the technical and managerial skills involved in a variety of innovation activities from R&D, design and engineering to technology brokerage and networking (Cirera & Maloney, 2018; UNCTAD, 2019a).
- Technical and R&D infrastructure: Infrastructure comprises basic technical infrastructure (e.g. water, energy, ICT, transport and urban structures), specialized infrastructure supporting R&D, demonstration and innovation processes (e.g. laboratories, testing and certification facilities), as well as existing technologies (UNCTAD, 2019a). Technical infrastructures (for example energy, transport and communications) are functionally interconnected.

National innovation systems (NIS) widely differ in terms of the levels of technological capabilities of their actors and the quality of enabling environment for innovation (Chaminade & Padilla-Perez, 2014; World Bank, 2010; Cirera and Maloney, 2017; UNCTAD, 2019ab; see Figure 1.3). They are internally diverse with pockets of excellence emerging in developing countries. For example, innovation systems in the least developed countries have poorly developed enabling environments often dominated by the informal sector and limited access to finance, lack of skilled labour, low quality technical infrastructure and weak and unstable regulatory and institutional framework. At the same time, however, such innovation systems may be less locked-in to unsustainable pathways and may have a wider range of local bottom-up social and inclusive innovation activities often rooted in indigenous knowledge (UNCTAD, 2019a).

Figure 1.3. Recognising the specific context of innovation systems

	Increasing innovation capabilities, with the potential to address societal challenges →
Actors and capabilities	Low technological and learning capabilities of actors Limited capability to address societal challenges but with relevant local examples of frugal innovation Mixed technological capabilities Mixed capabilities to address societal challenges with globally leading niches and sectors co-existing with underdeveloped and marginalized actors High technological capabilities and dynamic innovation/ entrepreneurial culture (including low-tech) combining to explicitly address societal challenges
Linkages and networks	Underdeveloped or missing linkages in the system Co-existence of well-connected technological areas and functional systems (e.g. energy, food) with underdeveloped and fragmented systems Highly developed linkages in the system Functional science-industry linkages High capacity to form public-private and public-public partnerships
Framework conditions and enabling environment	Weak enabling environment for innovation Rudimentary and/or not effectively enforced regulatory framework Limited or absent business advisory and financial support for innovation Good foundations of enabling environment with basic regulatory and policy framework Well-developed enabling environments, stringent but flexible regulation Highly developed entrepreneurial eco-system including in social and environmental fields Business advisory and financial support adapted to the needs of companies at different stages of innovation process

Source: UNCTAD (2019a)

The bilateral and multilateral STI collaborations are key for building and improving STI capabilities in developing countries. Many established collaborations and international organisations already emphasise the importance of capacity building as for example CGIAR. There is a need, however, to embed a more systematic understanding of STI capabilities in the design of international STI collaborations addressing the SDGs, considering the role and capabilities of different actors (firms, research, government and civil society) to actively engage and support different phases of innovation chain. The design should also consider the role of local and international networks and linkages in the system, as well as the wider framework conditions, including institutional and policy setting and R&D and science infrastructures.

The differences in STI capabilities between countries and actors involved in international collaborations need to be acknowledged to ensure a fair balance of responsibilities and investments between partners as well as to prioritise collaborative mechanisms which are accessible to partners at different levels of technological maturity. International collaborations should help developing countries to build critical capacity to understand risks and uncertainties linked to technology choices.

1.3. Joining forces for the Global Public Goods

One important dimension of tackling global challenges requiring STI collaboration between developed and developing countries is the provision of the Global Public Goods (GPGs), such as climate change mitigation, protecting natural environment on land and in oceans, sustainable global peace, ensuring financial stability or developing and sharing scientific knowledge for development of life-saving medicines and vaccines. Successful achievement of many SDGs depends directly on finding innovative and sustainable ways to supply the GPGs.

According to classical economics, pure public goods share two basic qualities: non-excludability and non-rivalry whereas private goods are excludable and rivalrous in consumption. Non-excludability means that once provided the public good is available to all to consume whereas non-rivalry means that consumption of the public good by one party does not reduce the amount available to the others. International Task Force on Global Public Goods (ITFGPG) defined GPGs as those public goods which "cannot or will not be adequately addressed by individual countries acting alone and that are defined through a broad international consensus or a legitimate process of decision-making" (ITFGPG, 2006).

Ostrom (1990, 2008) made a vital contribution by focusing on subtractability of the resource units which allowed her to distinguish between public goods and common-pool resources (CPR). CPR is "a natural or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use" (Ostrom, 1990). Whereas crowding effects and overuse problems are irrelevant for public goods (e.g. weather forecast), they are chronic for CPR where overconsumption can lead to temporary or permanent negative impacts on man-made structures or biological resources. The paper focuses on both public goods and CPRs (see Figure 1.4).

Figure 1.4. Typology of goods

	Higher subtractability of use	Lower subtractability of use
Higher difficulty to exclude potential beneficiaries	**Common-pool resources (CRPs)** Ecosystems, groundwater basins, irrigation systems, fisheries, forests, public health care systems	**Public goods** Open-access knowledge, Climate, Peace and security, International product and process standards
Lower difficulty to exclude potential beneficiaries	**Private goods** Food, clothing, electric cars	**Toll goods** Day care centres, private healthcare

Source: Classification of goods based on Ostrom (1990, 2008)

Barrett (2007) proposed a typology of GPGs considering key mechanisms on which the supply of GPGs depends, including single best effort, weakest link, aggregate effort, mutual restraint and coordination. These different mechanisms require different forms of STI collaboration (see Figure 1.5).

Figure 1.5. Barrett's typology of Global Public Goods supply

	Single Best Effort	**Weakest Link**	**Aggregate Effort**	**Mutual Restraint**	**Coordination**
GPG supply depends on	The single best (unilateral or collective) effort	The weakest individual effort	The total effort of all countries	Countries not doing something	Countries doing the same thing
Rationale for international collaboration	To determine what should be done & who should bear the costs	To establish minimum universal standards for all to apply	To agree on individual actions to achieve the common goal	To agree on what countries or other actors should not do	To choose a common standard
Examples of STI actions	R&D collaboration on vaccine for disease outbreaks; Scientific collaboration and infrastructure for early warning systems (e.g. extreme weather events)	Collaboration and information exchange between national health systems to implement a common response to pandemics and disease eradication	STI collaboration on fostering technology diffusion and building absorptive capacity to implement low-carbon clean technologies.	Agreements on international bans on research on topics deemed harmful.	Agreements on performance or technical standards ensuring a better interoperability and efficiency of technical systems.

Source: Classification of goods by Barrett (2007); Relevant examples and SDGs added by authors

International STI collaboration and the GPGs

Traditional approach to public goods suggests that they are to be supplied by governments or by government-funded actors. The scale, interconnectedness and complexity of challenges linked to GPGs requires international STI collaboration.

The rationale for international co-operation in STI for the GPGs is manifold:

- Developing international incentive regimes: Domestic and international markets are currently not designed to incentivise provision of the GPGs or to prevent (or account for) the negative social and environmental impacts of growing consumption and production on the CPRs;
- Strengthened innovation potential: Providing systemic and comprehensive solutions for societal challenges exceeds the capacity of single states or any other actor;
- Global deployment capacity and mechanisms: Concerted co-operation is essential to deliver solutions in acceptable timeframes to avoid approaching environmental tipping points or to be able to respond to severe societal crises (such as pandemics or natural disasters);
- Higher STI investments: There are major problems to scale up necessary investments;
- Sharing risk and cost of experimentation: Sharing risk and facing uncertainty to collectively explore and experiment alternative innovation pathways.
- International learning and knowledge sharing: Creating international learning environments to exchange experience and knowledge on common challenges.

On the one hand, international STI collaboration can help individual countries to improve their STI systems and build STI capabilities by learning from international experiences and benefiting from external sources of knowledge, human capital and finance. The improvements can enable them to better absorb existing technologies as well as generate new knowledge and innovation. This is particularly relevant for developing countries. In many cases, country-level and local improvements contribute to regional and (directly or indirectly) international benefits for GPGs and CPRs which depend on aggregate effort. For example, developing local renewable energy capacity supported by international collaboration creates local benefits but it also contributes to climate mitigation efforts worldwide. This is an example in which providing access to toll goods (i.e. electricity network) driven by economic rationale contributes to the GPGs (i.e. climate).

On the other hand, international STI collaborations can address bottlenecks in knowledge and technology flows on the global level and contribute to building *shared* global STI capacities to supply or safeguard the GPGs and CPRs. In this sense, rather than strengthening national STI systems, international collaborations improve global STI system and build shared capabilities of STI system to collectively tackle global challenges and supply GPGs. This perspective focuses on improving coordination and coherence of international STI efforts needed to achieve sufficient scale and enhance efficiency and effectiveness of STI investments and activities aiming to accomplish the SDGs.

The scale and nature of societal challenges means that conventional intergovernmental STI collaborations are likely to be insufficient. There is a need for novel modes of multi-stakeholder international collaborations, including global private companies and NGOs. In 2006, the International Task Force on Global Public Goods argued that “innovative partnerships between [private and civil society actors] and governments are likely to be an ever more important part of the process by which global public goods are financed.” (ITFGPG, 2006).

More than 10 years after, the call for innovative forms of international collaboration and governance mechanisms resonates even stronger. Although there is a growing number of international initiatives mobilising STI for the GPGs and CPRs, international partnerships struggle to develop effective governance mechanisms, institutional arrangements and instruments to tap into an enormous potential offered by the global STI system. International STI collaborations could benefit from globally enforced market-based mechanisms incentivizing investments and actions for the SDGs (e.g. global carbon price). It is clear, however, that relying on an imminent arrival of any such globally enforced instrument is not a sound strategy. While striving for a better global framework, international STI collaborations need to search for innovative forms of international multi-stakeholder collaborations on the bilateral, mini-lateral and global levels.

2. The current landscape of STI financing in sustainable development [OECD]

International development cooperation is one important mechanism to help drive science, technology and innovation (STI) for sustainable development. This section surveys the role and magnitude of official development finance (ODF) in support of STI using a number of different approaches. In doing so, the section highlights the need for the development and STI communities to further refine definitions, methodologies and data collection and points to a number of other important issues including the need for better coordination between national and international funders, the importance of data for philanthropy and development, and how the international community can further this vital agenda through various fora including the UN STI Forums and the OECD Blockchain Policy Forum.

2.1 The role of official development finance for STI

International development cooperation can support many aspects of the STI for sustainable development agenda. ODF can fill important gaps where the private sector lacks incentives to intervene by contributing towards strengthening the business environment to create markets, support key infrastructure projects with concessional or non-concessional financing and use blended finance to mobilise additional resources from the private sector (Table 2.1).

Table 2.1. Key development finance terms and definitions

Abbreviation/Term	Definition
Blended Finance	Blended finance is the strategic use of development finance for the mobilisation of additional private capital flows towards sustainable development in developing countries.
Concessional Finance	Financing extended on terms substantially more generous than market ones. The concessionality is achieved either through interest rates below those available on the market or by grace periods, or a combination of these.
Non-Concessional Finance	Financing is provided with a market-based interest rate
Official Development Assistance (ODA)	Resource flows to countries and territories on the OECD DAC List of ODA Recipients (developing countries) and to multilateral agencies which are: (a) undertaken by the official sector; (b) with promotion of economic development and welfare as the main objective; (c) at concessional financial terms.
Official Development Finance (ODF)	It is a broad measure of developing countries' official receipts for developmental purposes, and it is defined as the sum of bilateral ODA flows, bilateral OOF except OOF grants and loans for commercial purposes, and all grants and loans by multilateral development institutions, irrespective of the grant element of the loans.
Other Official Flows (OOF)	Transactions by the official sector with countries on the DAC List of ODA Recipients which do not meet the conditions for eligibility as Official Development Assistance, either because they are not primarily aimed at development, or because they have a grant element of less than 25 per cent.
Export Credits	Loans for the purpose of trade and which are not represented by a negotiable instrument. They may be extended by the official or the private sector. If extended by the private sector, they may be supported by official guarantees.
Grant	Transfers made in cash, goods or services for which no repayment is required.
Loan	Transfers for which repayment is required
Multilateral Agencies	International institutions with governmental membership which conduct all or a significant part of their activities in favor of development and aid recipient countries
Bilateral Flows	Flows that are provided directly by a donor country to an aid recipient country
Multilateral Flows	Flows that are channelled via an international organisation active in development

Source: Authors

For example, while investments in information and communication technologies (ICT) infrastructure and related services continue in industrialized and emerging economies to be driven by private actors or government entities and corporations, similar investments in many low-income countries remain limited. In terms of ICTs development, the private sector has less incentive to invest in broadband development in rural areas because of the high costs in connecting villages over longer distances with low population density. In these cases, governments and development cooperation providers need to step in with regulation, legislation, and direct or indirect financing, e.g. through tax incentives, subsidies or directly funding projects. Moreover, Official Development Assistance (ODA) resources can contribute to basic research and help find solutions to “grand challenges”, such as climate change and infectious diseases, which disproportionately affect less developed countries.

Concessional finance plays a critical role in creating the framework conditions in which new technology can be adopted and diffused rapidly and innovation can thrive. Whilst adoption lags of key technologies between poor and rich countries have converged over the past number of decades, the intensity of use of adopted technologies of poor countries relative to rich countries has diverged (Comin & Mestieri, 2018). Many reasons exist for this divergence including financing, infrastructure, knowledge and education gaps. Basic education and digital skills are crucial to help people in developing countries benefit from ICTs. Concessional development finance can support greater incorporation of digital trainings and ICT solutions in education systems. It can also be useful to support the digitalisation of government systems, including health and tax systems, for improved service delivery to previously marginalised communities (Dahlman, Mealy, & Wermelinger, 2016). Other important areas for the use of concessional finance include: supporting policies and implementation of initiatives for universal Internet access and the eradication of the digital divides, supporting local business and start-ups, and greater use of technological solutions to boost agricultural productivity, improve access to financial services, and strengthening systems for disaster risk reduction.

Concessional finance can also be used to support domestic capacity-building for STI, in terms of supporting basic research through higher education institutions, the training of scientific educators and researchers, the establishment of research institutions, and more. ODF thus plays an important role in terms of both building local capacity for STI in developing countries and accelerating scientific, technological and innovation diffusion across advanced, developing and emerging countries.

2.2 Overview of STI within the broader financing for development landscape

The remainder of this chapter surveys development finance going toward STI within the broader financing for development landscape. It provides estimates of official development finance to STI using a novel methodology; compares bilateral and multilateral providers; looks at the regional and sectoral distribution of financing; provides an overview of key bilateral funders (the United States, the United Kingdom, Sweden, Japan and Germany); explores some key trends in the field, such as blended finance and the growth of philanthropic funding for STI; and finally concludes with key findings.

2.2.1. Estimates of Official Development Finance to STI

The OECD has estimated the STI-related component of official development finance using a novel methodology. This methodology examines development finance for the three components of STI - science, technology and innovation - using a three-tiered approach: identifying STI “core activities” through the sector codes of the OECD Creditor Reporting System (CRS) Aid Activities database; identifying support to entities with an STI focus; and using text mining to find activities with an STI component (see Annex II). The analysis on technology is currently biased towards international support for ICT; however, technology transfers in other sectors, in particular green technology and renewable energy, are also included. As the current CRS structure does not lend itself to robust identification of activities supporting entrepreneurship or innovation, support to innovation may be underestimated.

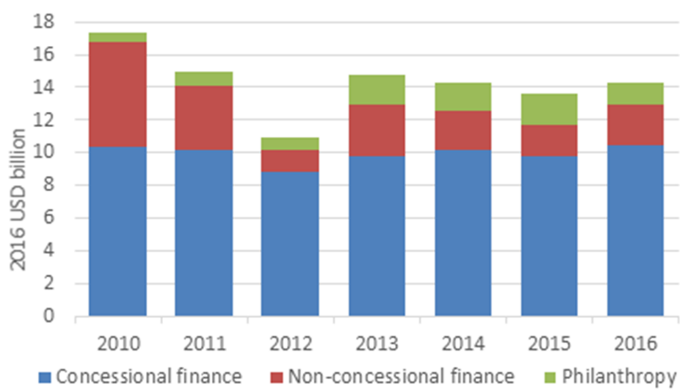
Total development finance to STI has fluctuated between USD 11 and 17 billion between 2010 and 2016 (Figure 2.1). The fluctuations are largely due to the volatility of non-concessional finance. Concessional finance to STI was USD 10.5 billion per year, representing 5.9% of total concessional finance by OECD Development Assistance Committee (DAC) members, multilateral organisations and other countries.

An earlier FAO analysis (Angelico, 2015) also based on the OECD CRS data found that out of the total ODA in the area of agriculture, forestry and fishing only about 7% was allocated to research (and 2% to extension). The analysis also showed that from 2002 to 2012, the shares of foreign assistance invested into research and extension had decreased or, at best, plateaued. It also showed that volatility in foreign assistance was causing challenges for planning and implementation (ibid.).

The largest share of concessional finance supports research related to development challenges, such as the prevention of diseases. Non-concessional finance represents a minor share of total development finance; however, it still represents nearly USD 3 billion per year, not counting export credits.[2] Non-concessional finance mainly consists of loans from multilateral development banks towards technology-related infrastructure projects, e.g. ICTs and renewable energy, and investments in raising countries' technological and innovative capacity. Private foundations' contributions towards STI, mainly targeted towards research in the health sector, represents a growing share of total development finance to STI.

Figure 2.1. Estimates of Official Development Finance to Science, Technology and Innovation (STI)

Disbursements in 2016 prices



Note: 2010-2012 Philanthropy data only includes Bill and Melinda Gates Foundation. 2013-2015 data come from the 2018 OECD Philanthropy Survey covering 143 foundations (OECD, 2018). The philanthropy data for 2016 only include Bill and Melinda Gates Foundation, Dutch Postcode Lottery and MetLife Foundation.
Source: (OECD, 2018a)

It is important to note that the methodology used to arrive at these estimates has limitations (outlined Box 2.1 and in the Annex II) and other approaches are possible. For example, the World Bank (WB) estimates that the total amount of bilateral development finance towards STI from the top five donor countries (US, Germany, UK, Japan and France) was around USD 9.5 billion in 2017 (points summarized in Boxes 2.3 and 2.4, and methodology outlined in the Annex III) (Kanehira et al., 2020 *forthcoming*). It is important to continue sharing, comparing and refining methodologies to improve the accuracy of all STI-ODA estimates, while addressing the challenge of collecting data on STI-focused aid projects.

[2] Export credits are not included in this analysis because of lack of data.

Box 2.1 Challenges for measuring development flows supporting STI

Measuring ODA to STI raises a number of challenges around the definition of concepts, and the availability, collection, reporting and disaggregation of relevant data. STI itself is a broad concept, encompassing research activities and training, the development of new technologies and other forms of innovation to increase the stock of knowledge and productivity. As such, STI is often not considered as a sector in itself as STI activities cuts across all sectors. Measuring it is thus difficult.

There are two main approaches to assess the portion of ODA in support of STI: examining government budgets and assessing individual development activities. These two approaches, which can be considered as "top-down" or bottom-up", have different benefits and limitations. The available data of both approaches come from different sources designed for different purposes. They also come with challenges as to the definitions used and purpose and scope of the analysis, for which there are differences between the development and STI communities.

Measuring financing to STI through government budgets may conform to standard STI definitions and guidelines, such as the definitions of R&D and innovation outlined in the OECD Oslo and Frascati Manuals, but will have limitations on the comparability with other ODA spending. ODA is a post-measure of the expenditures of ODA-eligible activities for a given year, and while the budgets set the framework for development spending, it is not certain that all ODA-eligible spending for STI are captured in the development budgets. The amount identified may result in an underestimation of total support to STI as individual projects or programmes not captured in detail in the budget may include STI-related components. In addition, a budget view of STI-related ODA would not necessarily allow for disaggregation of activities by recipient country or type of aid, thus making ODA to STI not comparable to other cross-cutting themes and measures. It may also be difficult to properly assess the amount of ODA that supports STI from a developing country perspective.

The other approach is measure ODA financing to STI through analysing individual development activities, which is followed in a recent OECD working paper (Ericsson & Mealy, 2019). OECD Development Assistance Committee (DAC) statistics are the only source of reliable and comparable data on development assistance. These statistics are collected in the Creditor Reporting System (CRS) database, which provides a set of readily available basic data that enables analysis on where development assistance goes, what purposes it serves and what policies it aims to implement, on a comparable basis for all DAC members, some non-DAC members and a number of multilateral organisations. These data do not cover several large players in development cooperation, including China and India.[1]

Each year, roughly 250,000 records (each containing up to 50 fields of information) on development activities from countries, multilateral agencies and private actors are submitted and stored in the CRS. This makes the CRS a goldmine for assessing development activities targeting different themes and sectors. Data are collected on individual projects and programmes and the focus is on financial data, but some descriptive information is also made available. However, whilst providing valuable information about specific development projects and programmes, these descriptions do not provide the necessary details to assess whether such activities conform to the official STI definitions in the Oslo and Frascati Manuals, or other international classifications, such as the International Standard Industrial Classification (ISIC) or the Classification of the Functions of Government (COFOG).

To overcome these challenges, the development and STI communities need to continue to engage with each other and discuss possible ways forward. The measurement of R&D and ODA are similar in the way that they both have long histories and detailed and internationally agreed definitions. However, with the focus on the attainment of the SDGs, their paths have crossed. The development community is increasingly interested in research, innovation, and the use of new technologies to improve development results. And vice versa, the STI community is increasingly interested in assessing their impact on development and the SDGs. Measuring progress in these areas are crucial and of great policy relevance; however, any new measure should be the result of a consolidated effort by both policy communities to understand the rationale for each system, including their benefits and limitations, and build upon their combined strengths. The OECD DAC and the OECD bodies responsible for STI statistics, namely the OECD Working Party of National Experts on Science and Technology Indicators (NESTI) within the Committee for Scientific and Technological Policy (CSTP) and the OECD Working Party on Measurement and Analyses of the Digital Economy (MADE) within the Committee on Digital Economy Policy (DEP) can play a key role towards that end.

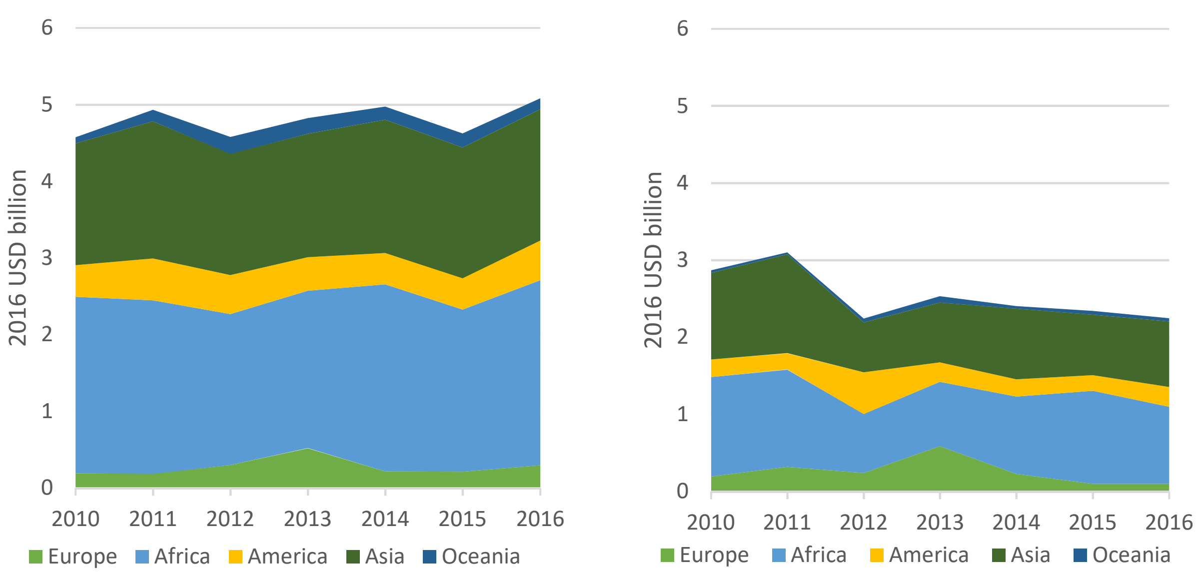
2.2.2. Where does official development finance on STI go?

Concessional finance is mainly allocated to countries in Africa and Asia (Figure 2.2). The top recipient countries of STI-related concessional finance are low and middle-income countries in East Africa, such as Tanzania, Kenya, and Ethiopia, or countries in Asia, including Afghanistan, Indonesia, India and Pakistan. Most STI towards these countries are going through universities or projects which includes a research or technological component, representing on average 5% of the concessional finance received.

However, there are wide discrepancies across countries with core research activities representing one-quarter or more of total STI resources in Ethiopia and India, but less than 5% in Indonesia and Pakistan. In Ethiopia, Kenya, and Pakistan, support towards ICTs represents less than 1% of total support to STI, while more than 10% of STI resources are targeting ICT development in Indonesia and Tanzania.

Figure 2.2. Concessional finance to science and innovation (left) and technology (right) by region, 2016

Disbursements in 2016 prices

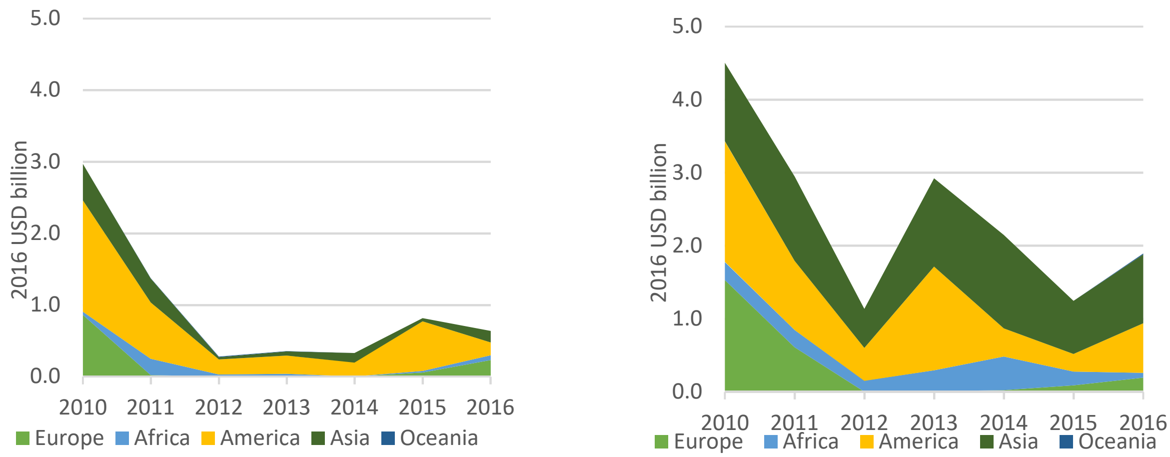


Note: The chart showing concessional finance to STI by region excludes finance that is reported as globally unallocated. The sum of the two charts will exceed total support to STI because of activities contributing to both science/innovation and technology.
Source: (OECD, 2019a)

Non-concessional finance is volatile and mainly supporting upper-middle income countries (Figure 2.3). Considering that non-concessional finance mainly consists of development loans that do not qualify as ODA, the recipients of non-concessional finance are mainly countries with acceptable credit rating and borrowing capacity. Most non-concessional finance to STI are allocated to upper-middle income countries in the Americas and in Asia, in particular Argentina, Brazil, China, India, and Mexico. The largest providers of non-concessional finance to STI are the Asian Development Bank, European Union (EU) institutions (incl. EBRD), Inter-American Development Bank, Korea, and the World Bank (IDA and IBRD).

Figure 2.3. Non-concessional finance to science and innovation (left) and technology (right) by region (2010-2016)

Disbursements in 2016 prices.



Note: The sum of the two charts exceed total support to STI because of activities contributing to both science/innovation and technology.
Source: (OECD, 2019a)

2.2.3. Comparing bilateral and multilateral funders

Bilateral and multilateral funders employ different approaches in support of STI. Bilateral providers use almost exclusively concession finance, whilst multilateral agencies use both concessional and non-concessional finance to support STI (Figure 2.4). DAC members increased their spending on STI between 2010 and 2016, whilst multilateral providers decreased their spending in the same time, driven by a decrease in concessional and non-concessional loans from the World Bank[3]. Non-DAC providers' support to STI is marginal but is growing, represented by the growing number of non-DAC providers reporting development finance flows to the CRS.

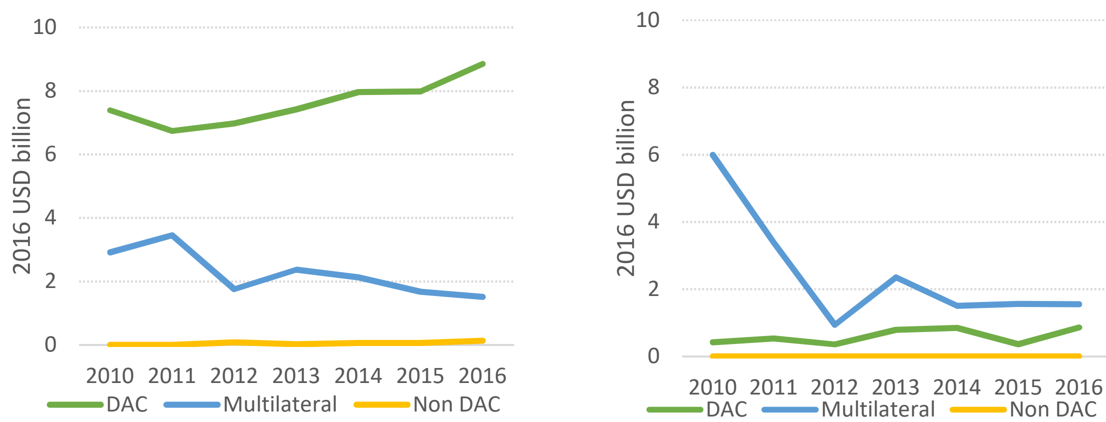
Box 2.2. Funding mechanisms vary across science, technology and innovation

Grants finance the majority of support to science and innovation. More than 90% of total Official Development Finance (ODF) towards science and innovation is financed by grants. Bilateral funders provide the majority of grants, although private philanthropic funders are increasingly important for universities and other research institutions. Multilateral agencies' contribution is split between grants and loans. Both concessional and non-concessional loans are mainly provided to the recipient government with the aim of strengthening higher education. We lack good data on non-philanthropic private finance, such as equity. There is greater variety regarding funding mechanisms for technology deployment and diffusion. Concessional and non-concessional loans represent half of all ODF towards technology, with greater participation of multilateral agencies. The majority of all finance from multilateral agencies are extended in the form of loans. Support from private philanthropy represents a minor share of total support of technology-oriented development finance.

[3] The drivers of this sharp decline, while warranting further analysis, may include graduation of formerly IBRD-eligible borrowers and availability of complementary sources of financing (e.g. European Union's Instrument for Pre-Accession Assistance) in Europe, among others.

Figure 2.4. Concessional (left) and non-concessional (right) finance to STI by provider

Disbursements in 2016 prices

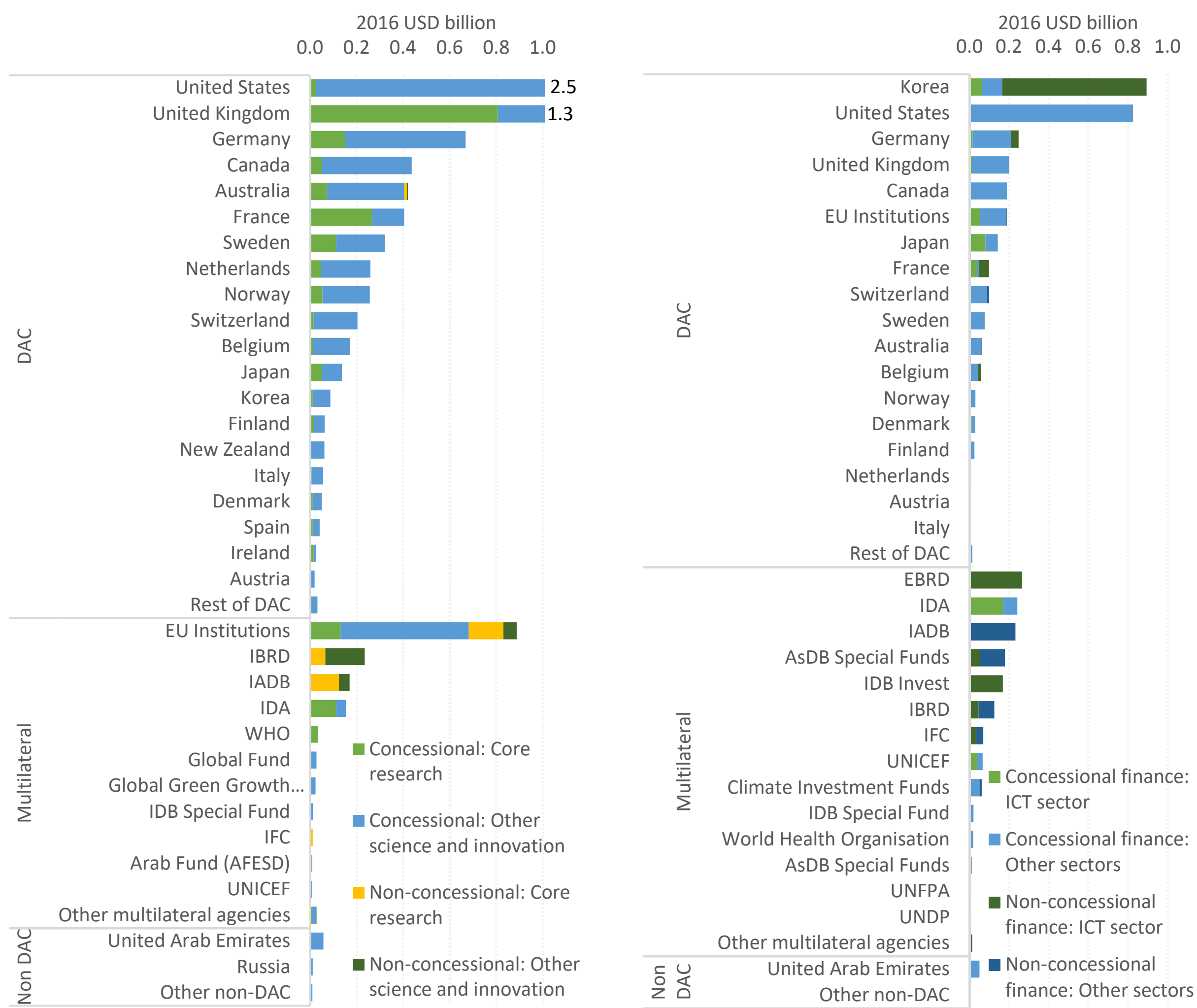


Source: (OECD, 2019a)

Concessional finance from DAC members in support of STI increased from USD 7.4 billion in 2010 to USD 8.9 billion in 2016. The US is the largest provider of concessional financing to STI, with a strong commitment to research and innovation in the health sector. The UK is also a big provider, having recently scaled up its effort to support research for global challenges. Together, these two countries provide half of the DAC members' total support to STI. However, other countries, such as Australia, Canada and New Zealand, provide a greater share of their total bilateral ODA as support to STI (Figure 2.5).

Figure 2.5. Top development providers supporting science and innovation (left) and technology (right), 2016

Disbursements in 2016 prices



Note: The sum of the two charts will exceed total support to STI because of activities contributing to both science/innovation and technology. Core research refers to research activities classified according to one of the nine research sector codes in the CRS. ICT sector refers to activities that have been reported against the four sector codes for communication in the CRS. Commitments were used as proxy for disbursements for the Caribbean Dev. Bank, Global Environment Facility, IDB Invest, IFAD, IFC, and the Islamic Dev. Bank.
Source: (OECD, 2019a)

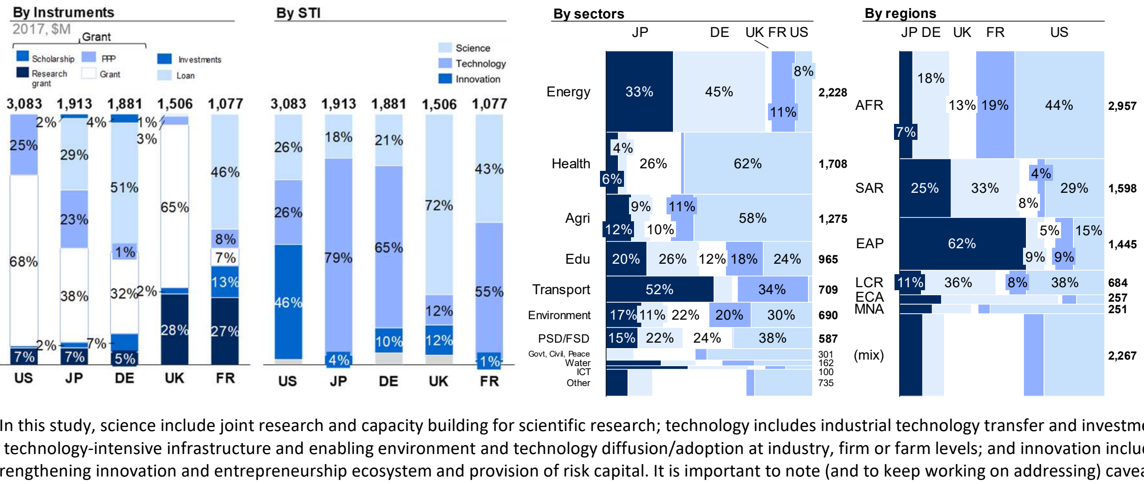
Box 2.3. Deeper look into major donors' STI-ODA intersection activities

The World Bank examined the intersection between STI and ODA programs of the five countries with largest ODA disbursement (US, Germany, UK, Japan and France), through project-level assessments against STI characterization in formal SDGs languages, using CRS and complementary national data, and validation with national counterparts (detailed methodology in Annex III), and found the total of around USD 9.5 billion disbursement by the five countries in 2017. In combination with UN/WB's analysis of multilateral STI activities that identified the stock of USD 120 billion for recipients as of 2015 (IATT, 2017), WB estimates that bilateral and multilateral ODA to support STI in developing countries can be over USD 20 billion annually.

While approaches to national accounting of ODA and STI vary across these five countries, the STI-ODA intersection roughly represents 10% of ODA budget in each country, and its ratio to STI (or R&D) budget ranges from 2% (US) to over 10% (UK). Findings complementary to OECD includes:

- Composition of science, technology and innovation* in STI-ODA intersection vary across the five donors, roughly corresponding to the mix of instruments per donor country, such as grants for strengthening innovation system and private sector partnership (US), loans for technology transfer through infrastructure investments (Japan, Germany) and research grants and scholarships (UK, France).
- WB analysis found substantial amount of additional activities, compared to OECD analysis, largely from Japan and Germany related to technology in energy and transport sectors. OECD analysis may include, but WB does not include, i) funds channelled through universities and not explicitly supporting STEM fields and ii) activities in ICT sector not involving technology transfer, such as provision of translated contents for broadcasting, largely from US and UK.
- Regional distribution of recipients in STI-ODA intersection areas largely reflects each donor's underlying ODA activities, while sectoral distribution does not (e.g. disproportionately high STI in energy from Germany, agriculture from US, transport from France); these indicate large rooms for mutual learning to increase "STI intensity" where needed and transfer good practices across regions, and to complement and strengthen multilateral and regional initiatives.

The analyses indicate potential sources of expertise, comparative advantages and complementarities when advancing further international STI cooperation, in addition to the coordination challenges on the recipient country sides, given developing countries' capacity constraints especially on STI.



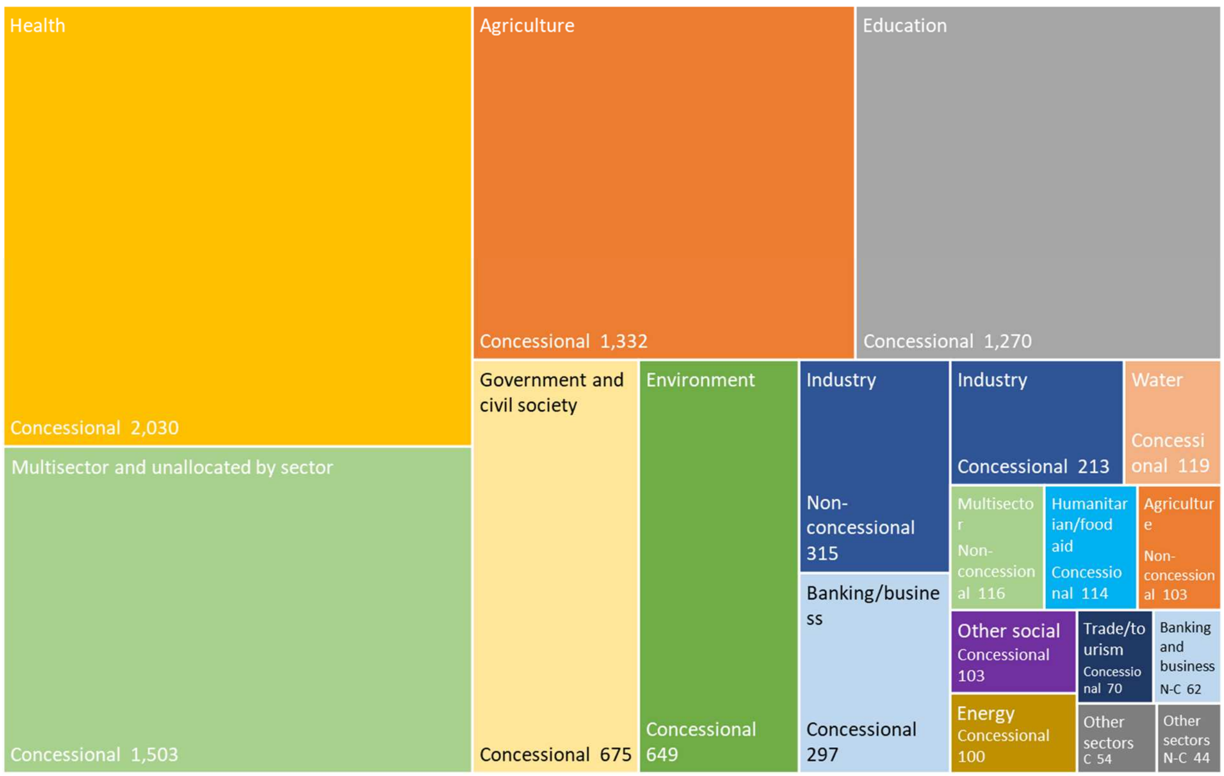
* In this study, science include joint research and capacity building for scientific research; technology includes industrial technology transfer and investments in technology-intensive infrastructure and enabling environment and technology diffusion/adoption at industry, firm or farm levels; and innovation includes strengthening innovation and entrepreneurship ecosystem and provision of risk capital. It is important to note (and to keep working on addressing) caveats related to data and concepts, as elaborated in Annex.

2.2.4. Which sectors are financed?

Health, agriculture and education were the sectors receiving the most amount of ODF support to science and innovation in 2016 (Figure 2.6). The focus areas in the health sector are infectious and STI-related disease control, including HIV/AIDS, and reproductive health.

Figure 2.6. Official Development Finance to Science and Innovation by sector (2016)

Disbursements in 2016 prices, millions



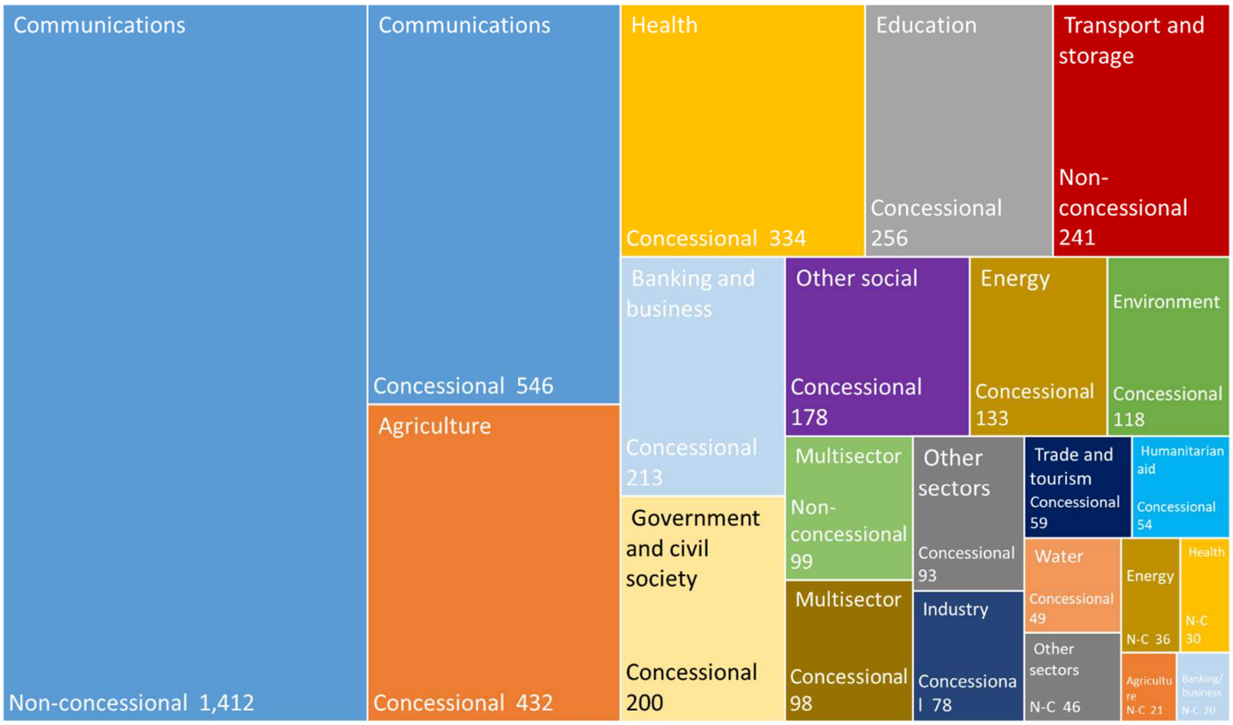
Note: The colours represent the different sectors. C is short for concessional and N-C is short for non-concessional financing. Activities classified as multisector are mainly support to research and scientific institutions.

Source: (OECD, 2019a)

The communication sector is the primary target of technology-oriented ODF (Figure 2.7). The ICT and telecommunication sectors are large receivers of non-concessional loans, mainly provided by multilateral development banks. Other sectors with ICT and technology focus are agriculture, health and the education sector.

Figure 2.7. Official Development Finance to Technology by sector (2016)

Disbursements in 2016 prices, millions



Note: The colours represent the different sectors. C is short for concessional and N-C is short for non-concessional financing. Activities classified as multisector are mainly support to research and scientific institutions.
Source: (OECD, 2019a)

2.2.5. Key donor profiles

The United States

The United States is the largest provider of concessional finance to STI, with a large share of its funding directed towards research, capacity building and innovative approaches to fight two global issues: firstly, the spread of infectious and tropical diseases and prevent maternal and child deaths; and secondly, the global food shortage and hunger. The World Bank estimates that in 2017, the US disbursed around USD 3.1 billion in STI-intensive ODA activities and about 46% of the total amount (USD 1.4 billion) was spent on innovation components (Kanehira et al., 2020 *forthcoming*).

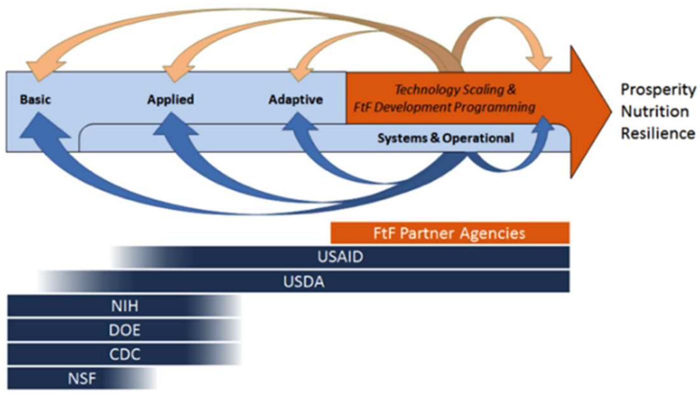
The United States Agency for International Development (USAID) Global Health Research and Development Strategy 2017-2022 aims to strengthen the capability of researchers, improve the evidence-based health and development interventions, and accelerate the development use of health technologies and approaches to address critical unmet needs and emerging challenges (USAID, 2017a). Many of its programmes, such as the U.S. President's Emergency Plan for AIDS Relief (PEPFAR), include significant research and innovation components, either directly through its activities or in partnerships with academia or research institutions. PEPFAR consists largely of non-scientific activities, yet science is recognized as its foundation so that its efforts are continuously guided by science (US DoS, 2012). According to the World Bank, PEPFAR allocated about USD 430 million in STI-centric projects, which is over 14% of its entire budget to perform clinical and implementation research to support the development of new technologies for HIV/AIDS prevention (e.g. microbicides, vaccines) and care (e.g. new treatments or treatment regimens) (Kanehira et al., 2020 *forthcoming*).

USAID reported their major achievement in the past years, and STI appear to hold a pivotal role in their efforts, while taking advantage of a whole-of-government approach and the use of multilateral forums. USAID focus is broad and covers a number of areas of intervention that embeds innovative components, ranging from food security to global health, including digitalisation and education (USAID, 2017b).

On the former, the Feed the Future (FtF) initiative seeks to bring together the private and public sectors and the global science and research community to pursue poverty eradication and the end of hunger and malnutrition by harnessing "the best of American ingenuity and innovation to create solutions, ease human suffering, and put communities and countries on a path to self-reliance" (US Government, 2018a)[4]. Those paramount objectives are under the FtF initiative, addressed mainly through innovation and research in the agriculture sector, where a network of more than 20 Innovation Labs, 70 U.S. Universities and partner-country education and research institutions developed new technological solutions and deployed more than 900 innovations to improve production efficiency and health condition of children in target countries.[5]

In 2016, a new law called the Global Food Security Act was passed, which made FtF a permanent program and called for a new whole-of-government global food security strategy with department and agency-specific implementation plans, developed in 2017. Accordingly, six US research funding agencies (dark blue bars) are tasked with contributing to different phases of the R&D and scaling pipelines, while the eleven FTF partner agencies (orange bar) primarily contribute to the FtF development programming. (See Figure 2.8) USAID, as the FtF lead agency, serves a critical role in coordinating the eleven FtF partner agencies. In addition to interagency coordination, USAID leads field implementation and monitoring and evaluation (M&E) while managing an array of agricultural development, nutrition and resilience projects that support FtF's goals, moving countries along a path toward self-reliance and leveraging partners, like the private sector and research community, for sustainable progress. The US Department of Agriculture (USDA) contributes to agricultural programs and activities that focus on capacity building, international food assistance, research, and the promotion of science-based solutions to expand markets and trade. Also, the US African Development Foundation (ADF) addresses, at the grassroots level, the root causes of hunger and food insecurity, providing seed capital and local technical assistance directly to small and medium agricultural enterprises to improve productivity, strengthen resilience and increase incomes for smallholder farmers.

Figure 2.8. R&D pipeline and the involvement of U.S. government agencies in different stages



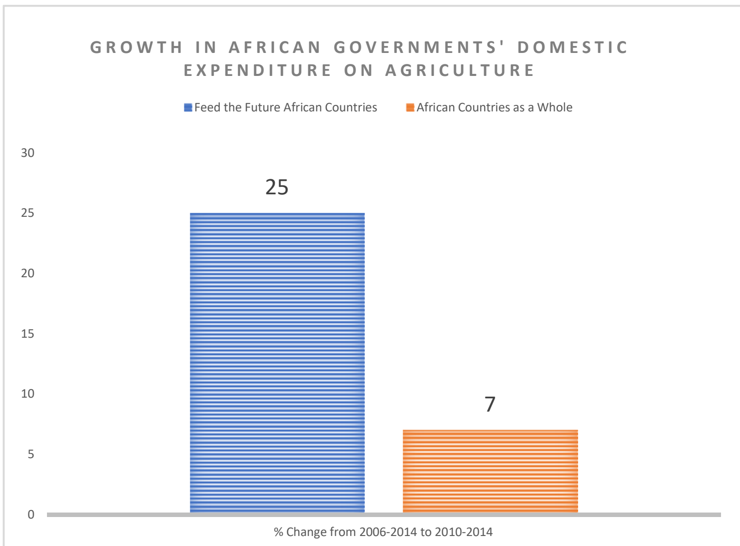
[4] Note that all the figures and statistics refer to the Feed the Future Progress Snapshot 2018, unless stated differently

[5] Bangladesh, Ethiopia, Ghana, Guatemala, Honduras, Kenya, Mali, Nepal, Niger, Nigeria, Senegal, Uganda.

Source: (US Government, 2018b)

The US also took an advantage of its G20 presidency to create a multilateral component of FtF. During the G20 Summit in 2009, President Obama called for the establishment of the Global Agriculture and Food Security Program (GAFSP), a multi-donor trust fund at the World Bank that provides various financing instruments for low-income countries to fund food security. Simultaneously, as FtF developed its R&D strategy, it ended up shaping the strategy of CGIAR, which is co-sponsored by FAO, IFAD, UNDP and WB as the development of the FtF R&D Strategy involved a series of consultation processes between top US universities and developing country research institutions, which primarily consisted of the CGIAR centres as they are funded to work together to provide expertise to FtF under the aforementioned Innovation Lab. FtF helped over 10 million smallholders farmers to use new technologies and had a catalytic effect on domestic investments into agriculture, resulting in an 18 per growth increase differential between FtF African Countries and African Countries as a whole, as shown in the Figure 2.9.

Figure 2.9. Growth in African governments' domestic expenditure on agriculture



Source: US Government (2018)

USAID supports innovation by engaging with partner countries on digitalisation of institutions. For instance, it is one of the co-founders of the Better Than Cash Alliance – a project that aims to digitalise institutional payments while tackling corruption, women's economic participation and financial inclusion (BTCA, 2019).

The United Kingdom

The United Kingdom is heavily scaling up support to research. In 2013, the UK Government announced its pledge to provide 0.7% of its gross national income (GNI) as ODA. Over the following three years, new research funds were set up to support research activities tackling challenges faced by developing countries, including the Newton Fund, the Ross Fund and the Global Challenges Research Fund (GCRF). A second aim of the research funds were also to benefit from the high-quality standard of research conducted in the United Kingdom.

As documented in UK strategy documents on foreign aid and national growth, UK intends to "meet (its) moral obligation to the world's poorest" (DFID, 2015) by aligning with the country's pursuit of its national interest in enhancing its "excellence in research and innovation though global engagement" (BEIS, 2017). The UK aid community strategically leverage "UK's world-leading science, research and development base to tackle global problems" (DFID, 2015).

While the Department for International Development (DFID) has committed to invest 3% of its budget to research, additional funding is expected to be provided through the new funds. ODA support from the United Kingdom towards research activities increased more than four times between 2010 and 2016, from USD 181 million in 2010 to USD 807 million in 2016 and is expected to further increase in coming years. The World Bank estimates that in 2017, the UK disbursed around USD 1.5 billion in STI-intensive ODA activities and about 72% of the total amount (over USD 1 billion) was spent on science components (Kanehira et al., 2020 *forthcoming*). GCRF, for example, supports North-South joint research targeting all of the SDGs with annual budget of approximately USD 500 million, totalling GBP1.5 billion between 2016 and 2021 (DFID, 2015).

The UK disburses more than 70 per cent of its ODA through the Department for International Development (DFID) (OECD, 2019b). But when it comes to "STI intensive" ODA activities, the role of industrial ministry is near as significant as the aid agency, as over 40% of STI-ODA expenditure was disbursed by the Department for Business, Energy and Industrial Strategy (BEIS). In fact, the above-mentioned research funds are channelled through both DFID and BEIS to support research activities in the UK and developing countries. Consequently, in 2017, the UK's focus areas of STI for SDGs were more at a global level or were implemented in mixed regions instead of targeting one specific region/country (Kanehira et al., 2020 *forthcoming*).

Perhaps to address the lack of prioritised areas, the UK announced in August 2018 a series of "Innovation Partnerships" with African countries with vibrant and growing tech sectors and young, expanding population. Namely, South Africa, Kenya and Nigeria. The rationale is to share the expertise of British entrepreneurs while benefitting from the potential of one of the fastest growing sectors in Africa.[6] Anecdotal evidence show that technology could transform society in those countries as happened in Kenya where a small UK aid contributed to the birth and explosion of the mobile-phone based money transfer MPesa (as per today half-of Kenya's daily GDP goes through mobile money).

Those programmes include dedicate STI teams to build on existing relationship with those countries as well as great efforts in supporting both financially (e.g. early-stage investment) and intangibly (e.g. digital skills trainings, coding programmes) African start-ups as part of the DFID Tech Acceleration Programme, a 32 million pounds scheme (UK Government, 2018)

The clear focus of the United Kingdom on research activities to support digital innovation for development is also witnessed by the Digital Innovation for Development in Africa (DIDA) call. This two-stage project that will articulate between November 2019 and early January 2021 will deploy to a first cohort of seed funded DIDA networks (individual project up to 12 months costing between GBP 100–150 thousand) a total of GBP 3 million and to six to eight project identified from a competitive second call additional GBP19 million over three years (each project costing between GBP 1 million - 3 million) (UKRI, 2019)

Another STI initiative, this time under the umbrella of the Prosperity Fund Programmes is the Green Growth Equity Fund that is a UK – India partnership on the National Investment and Infrastructure Fund. This project uses UK government finance to catalyse private sector investments into sustainable infrastructure projects in India. The NIIF main sectorial focuses will be on renewable energy, clean transportation, water treatment and waste management (with the entirety of the fund being attributed to climate change mitigation). Almost GBP 10 million out of a total project budget of GBP 130 million have been deployed up to date (DFID, 2019)[7].

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[6] African startups raised 50 percent more venture capital in 2017, compared to 2016. The majority of which is concentrated in three main countries: South Africa, Kenya and Nigeria

[7] Figures are updated to the 30/08/2019

Sweden

Sweden's research co-operation programme focuses on both strengthening the research capacity of developing countries and financing research projects. It is grounded in the government's "Strategy for research co-operation and research in development co-operation 2015-2021" (Sida, 2015). The aim of the strategy is "to contribute to strengthened research of high quality and of relevance to poverty reduction and sustainable development, with a primary focus on low-income countries and regions." While support to research co-operation has represented a minor share of Sweden ODA (roughly 2%), the Swedish Development Agency (Sida) is aiming to scale up its research co-operation programme following strong demand.

Japan

The Government of Japan spends USD 35 billion annually on public STI-related expenditure; additionally, the private sector spends USD 135 billion annually on its R&D (Cabinet Office of Japan, 2018). The World Bank estimates that Japan spent nearly USD 2 billion on the cross-sector of ODA and STI (Kanehira et al, 2020 *forthcoming*). Japan's ODA-STI related activities are largely infrastructure technology projects in Asia, financed by loans and public-private partnerships (PPPs). The country has comparative advantage in private sector development, through the Japanese International Cooperation Agency projects on improving firm capabilities and technology absorption (kaizen), quality infrastructure investment, universal health coverage and disaster risk reduction and management (DRR and DRM).

On disaster risk area, in particular, Japan has succeeded in shaping the global agenda through multilateral/global forums, such as mainstreaming "resilience" element through the UN SDGs, adopting Sendai Framework for DRR (2015-2030) during the World Conferences on DRR, and later producing and updating "science and technology (S&T) Roadmap to Support the Implementation of the Sendai Framework for DRR" in accelerating the Sendai framework. Japan demonstrates global leadership in this area while leveraging its technological advantages in building soft and hard infrastructures. According to the World Bank, the country's bilateral DRR/DRM expenditures in 2017 were characterized by research activities to support the development of national DRM plans by developing countries, feasibility studies of Japanese DRR-technologies, and building soft infrastructures such as early warning systems to protect local communities from natural disasters (Kanehira et al, 2020 *forthcoming*). Japan's presence tends to be prominent in East Asia and Pacific region but smaller in Africa.

Japan has indicated its interest in mainstreaming STI for SDGs through bilateral and multilateral forums to support developing countries develop and implement STI for SDGs roadmaps and help scaling up relevant activities, especially in the sectors Japan is strong at, such as DRR/DRM, quality infrastructure and universal health coverage.

Japan has formalized approaches to STI for SDGs roadmaps for development cooperation through integrating and coordinating the Government's relevant strategies:

- STI Plans: "The 5th S&T Basic Plan (Government of Japan, 2016)" and "Integrated Innovation Strategy" (Government of Japan, 2018),
- National Development Plans: e.g. "Growth Strategy" (PM's Office, 2019)
- SDGs Plans: "SDGs Action Plan" (MOFA, 2019) and "Priority Policy for Development Cooperation" (MOFA, 2018).

This policy coordination has been done in accordance with human-centric, STI-enabled "Society 5.0" vision elaborated first in its 5-year STI strategy (2016-2020). During its presidency of G20 and hosting the major Development Cooperation Conference in 2019, Japan led the adoption of related principles and action plans[8].

Germany[9]

Germany's recent development and co-operation strategy focuses on five macro areas, of which two closely relate to STI, namely digitalisation and climate change. (OECD, 2019b). On the former, the Federal Ministry for Economic Cooperation and Development (BMZ) reports that their portfolio rose from 223 to 482 projects with digital components between 2015 and 2018. Africa and Asia are the two most targeted regions, with 181 projects (37% of the total) targeting the former and the latter counting 131 projects up to date.

According to the World Bank's analysis on STI-ODA intersection areas, Germany provided USD 1.8 billion on STI intensive development aid activities in 2017, largely through loans, together with a relatively small percentage of regular grants. Out of the expenditure, 64% (USD 1.2 billion) was used on technology-intensive infrastructure construction and relevant technology transfer, especially in the renewable energy and energy efficiency field in mitigating climate change. German disbursement of its ICT sector recorded in 2017 was around USD 30 million, but considering the significant commitments explained below, the small figure was probably due to disbursement delay (Kanehira et al., 2020 *forthcoming*).

The main effort to create "an innovative tool for firmly linking development cooperation and the digital world" is represented by the Digital Africa Initiative (DAI) with almost 40 projects with a volume of EUR 164 million between 2015 and 2018. Those projects are carried on by the KfW Development Bank together with the Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ), on behalf of the BMZ. The emphasis of the DAI is on connecting Africa and Germany, especially its private sector. Even if part of the efforts of the DAI directly go into supporting the expansion of broadband and energy infrastructures e.g. in Cameroon and Cote d'Ivoire (BMZ, 2017a), the main objective remains harnessing digital transformation by transferring knowledge and proving partner countries with solutions that could support more efficient procedures.

One of the main goals/areas of intervention of DAI is to increase work and employment in developing countries by making use of public and private partnership-type of intervention, such as the Strategic Partnership Digital Africa (SPDA) for which the BMZ budgeted to deploy EUR 28 million over 3 years. The SPDA refers to a network in which the BMZ, together with industry associations and private companies (more than 150 enterprises including large firms such as Volkswagen, SAP and Siemens as well as small and medium enterprises) implement on-field business project (BMZ, 2018) as well as knowledge sharing projects such as training programs followed by assistance in local job placement (SAP, 2019). Meanwhile, the DAI promotes local innovation through the Digital Transformation Centres in Africa (EUR 7 million budget) to support entrepreneurs and investors as well as African governments in building capacity for implementing digital solutions by fostering on-field technical know-how development. The DAI is designed to increase equal opportunities through projects, such as Africa Cloud (EUR 10 million) that offers to selected target groups in Africa digital knowledge and high-quality learning material, often in partnership with German tech companies; Digital solutions are also employed e.g. to improve quality of medical care in fields for prevention, early detection and treatment.

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[8] G20 adopting i) Guiding Principles on STI for SDGs Roadmaps (para 28 of Leaders' Declaration, and Annex); and ii) Plans for Action on Digitalization for SDGs (para 35-37 of trade and digital ministerial declaration); and TICAD 7 (Tokyo International Conference on African Development) adopting Yokohama Declaration and Yokohama Plan of Actions.

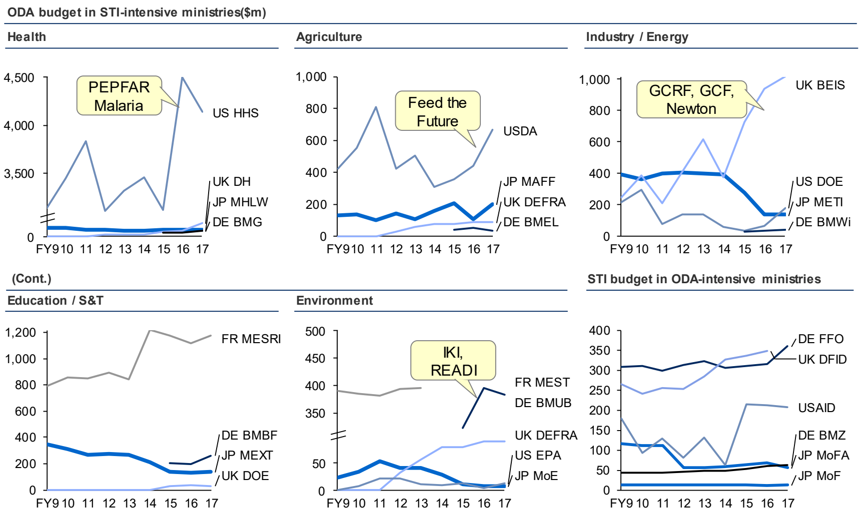
[9] Note every budget figure in this section refers to data provided in (BMZ, 2019) unless differently stated.

Climate change is the other core STI-related focus of Germany's recent development and co-operation strategy. On this matter Germany recently promoted the "Green People's Energy for Africa" (GPE) initiative with the objective to complement the interventions put in place together with G7 countries as a result of the Paris climate agreement. The GPE aims to "eradicate energy poverty and help out Africa on a climate-friendly development path" (BMZ, 2017b). This initiative builds on the expertise that Germany developed from the energy cooperatives model during their rural electrification efforts and currently as a support to their energy transition. (BMZ, 2017b). GPE mimics successful multilateral partnerships, and Germany plans to provide green energy to 500 SMEs over the next 5 years; Some 50% of which should be in the agricultural sector. Moreover, following the aforementioned cooperative model, Germany aims to assist 8 countries in putting in place the right legal and administrative environment to establish 100 "people's energy partnerships" by 2022.

Box 2.4. Institutional and budgetary contexts of major donors' ODA-STI intersection activities

The World Bank's analysis found that donor countries have varying practices in budgeting and programming STI-ODA intersection by line ministries responsible for STI as well as finance /foreign/development ministries responsible for ODA. The following figure summarizes i) trends of ODA budget in line ministries, and ii) STI or R&D budget in finance/foreign/development ministries across the five countries WB analysed. While the former includes ODA not necessarily with STI, and the latter includes STI not necessarily for development cooperation, budget patterns are indicative of each country's priorities. Key takeaways include:

- Line ministries have budgetary backing in areas with demonstrated leadership (e.g. US on health and food; Germany on environment, UK and France on research cooperation)
- Some development agencies are increasing emphasis on STI (UK, Germany, US)



Abbreviations

US: Department of Health and Human Services; US Department of Agriculture; Department of Energy; Environmental Protection Agency; US Agency for International Development

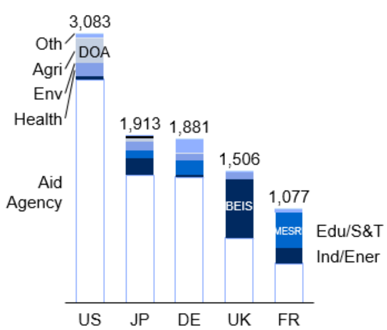
UK: Department of Health and Social Care Department of Environment, Food & Rural Affairs; Department of Business, Energy & Industrial Strategy; Department of Educati Department for International Development

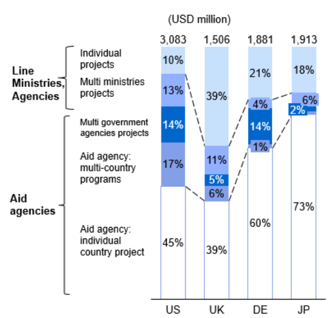
Japan: Ministry of Health, Labour and Welfare; Ministry of Agriculture, Forestry a Fisheries; Ministry of Economy, Trade and Industry; Ministry of Education, Culture, Sports, Science and Technology; Ministry Foreign Affairs; Ministry of Finance

Germany: Federal Ministry of Health (BMG Federal Ministry of Food and Agriculture (BMEL); Federal Ministry of Economic Affa and Energy (BMWi); Federal Ministry of Education and Research (BMBF); Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMUB) Federal Foreign Office; Federal Ministry fo Economic Cooperation and Development (BMZ)

France: Ministry of Higher Education, Research and Innovation (MESRI); Ministr for the Ecological and Solidary Transition

- Aid agencies are the primary channels to deliver STI-ODA in US, Japan and Germany (USAID, JICA, giz/KfW) while line ministries play greater roles in UK, France (BEIS, MESRI).
- Yet, aid agencies play varying roles in inter-ministerial coordination and programatization of proven approaches. US and Germany give their aid agencies greater roles in all-government approaches; UK and French line ministries have larger share of programs not through aid agencies; Japan's aid agency more independently delivers discrete projects.



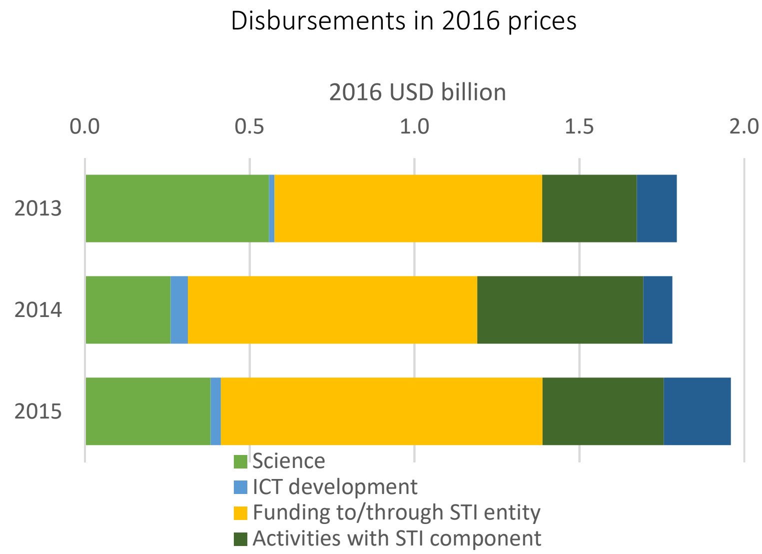


Given the cross-cutting nature and domestic-international tensions around STI for SDGs as discussed in the next chapter, there have been limited analysis and deliberation in this area. More can be done to better align relevant policy objectives and boost collective performance.

2.2.6. New trends in supporting STI for sustainable development: the role of private philanthropy

Private foundations are becoming increasingly big players in development cooperation. A recent OECD report estimated that total private philanthropy for development amounted to USD 8 billion per year (OECD, 2018). Whilst this amount is still small relative to official development finance, foundations are playing a significant role in certain sectors, for example, health. Based on the resources spent by 143 foundations over the years 2013-2015, foundations' support was the third-largest source of financing in the health and reproductive health sectors. Nearly one-quarter of total support provided by foundations targets STI activities and initiatives (Figure 2.10).

Figure 2.10. Private Philanthropy to STI (2013-2015)



Note: This chart only shows data for the years 2013-2015
Source: (OECD, 2018)

2.3 Key findings

Measuring and characterizing Official Development Finance to STI is critical in identifying trends and gaps, assessing efficiency and effectiveness, and informing policy dialogues and learning to better harness STI in addressing development challenges. Yet, it is difficult due to conceptual difficulties, data limitations and lack of established (or variations in emerging, if any) methodological approaches. The various measurement and policy communities need to continue working together to approximate toward more accurate and better aligned measures and definitions. This work is already a good step in that direction.

Using the OECD and WB methodologies, concessional finance to STI is estimated to be at least USD 10 billion. It could, however, be over 20 billion per year[10], representing 6 to 10 per cent of total

[10] Top 5 donor countries (US, Germany, UK, Japan and France) disbursed USD 9.5 billion in bilateral STI-ODA intersection activities in 2017 (Kanehira et al., 2020 *forthcoming*). The WB estimated that G20 countries spend potentially USD 20 billion annually in development assistance, including billions through MDBs, to promote STI (MoF Japan, WB & ADB, 2019). Taking account of resources from other donors, including Nordic countries, the total concessional finance to STI (combining all bilateral and multilateral contributions) could be over USD 20 billion per year. Note that estimation of annual disbursement of

concessional finance by DAC members, multilateral organisations and other countries. Given that STI can be a primary or secondary element of various programs and that it is challenging to assess the overall importance of STI in larger cross-cutting initiatives analysed in these estimates, it is debatable whether this remains a small proportion against potentially transformative effect that STI can have on developing countries. Innovative ways to increase this amount should be explored, while strategies, coordination and governance mechanisms at national and international levels may be considered in maximizing impact from the use of these resources. At the same time, it would be helpful to improve the monitoring system to better track of STI-enabled development aid, ensuring the quality of relevant statistical data.

The challenges lie in both the scale and orientation of STI funding. Private philanthropic funding for STI in developing countries is growing but how can this and other innovative ways of financing STI be scaled up? Market channels for flows of technology and innovation are significantly larger than philanthropic or ODA flows. What incentives and regulatory, market-based measures could increase their fit for the SDGs?

At global level, knowledge and experience sharing, dissemination and application of good practices, and possibly designing new or improving existing mechanisms can better be informed and targeted through concerted analytical and facilitation efforts. For example, UN STI Forums, while positioned as an apex forum for global multi-stakeholder dialogues on STI for SDGs, have not discussed STI-related lessons from US PEPFAR or Feed the Future in the sessions dedicated to Goals 2 and 3 over the last years.

At national level in donor countries, there can be rooms for better alignment of policy objectives, funding, inter-agency coordination and programming / governance of STI through development cooperation, depending on respective national circumstances and benefiting from further international benchmarking and experience sharing.

At national level in many developing countries, given the heterogeneity of actors and programs involved, it is highly likely that STI-related efforts can better be coordinated and synergized among development partners, in context of national strategies, institutions, investments and initiatives typically under capability and funding constraints. Countries piloting national STI for SDGs roadmaps[11] can explicitly tackle this issue through the design and implementation of the roadmaps.

This chapter provided an overview of STI through official development assistance, with its focus on developing countries as direct recipients. But impact of STI in achieving the global goals is broader, including through international cooperation among developed countries in providing global public goods such as climate change mitigation measures indirectly affecting developing countries. The next chapter will provide an overview current international STI collaborations focusing on barriers and drivers and key lessons for international STI collaborations addressing the SDGs.

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multilateral STI-ODA activities is challenging; the figure could potentially be over USD 20 billion, considering that (IATT, 2017) identified approximately USD120 billion stock of multilateral resources for STI-related AID activities, including USD 80 billion with a broad focus, in which STI is a smaller component or have indirect effects. In calculating the multilateral contributions, a conservative estimate should at least include “primary” STI initiatives by the UN agencies and the WB, mapped by (IATT, 2017): around 1,000 staff, USD 400 million annual budget and USD 40 billion resources for recipients, consisting of USD 10 billion grants and trust funds and USD 30 billion loans and credits, (which could be translated to annual expenditures of around USD 2.5 billion for grants and trust fund plus around USD 3.4 billion for loans and credits).

[11] The first phase of the UN Global Pilot Programme on STI for SDGs roadmaps was announced during the HLPF, in July 2019, focusing on 5 pilot countries: Ghana, Ethiopia, Kenya, India and Serbia. See https://sustainabledevelopment.un.org/partnership/?p=33852

3. Drawing lessons from international STI collaborations

3.1. Rationale of international STI collaboration

STI collaborations are, by and large, national activities, but they also have a long history of internationalisation and globalisation. International STI collaboration is driven by various push and pull factors such as global competition, limits on national research funds and the need to share costs as well as the need to access research resources or share observational or experimental research data.

Conventional rationale for international STI collaboration between nation states can be explained by three main principles, including the pursue of national self-interest, reciprocity and the capability of national STI systems (OECD, 2018). These principles have guided international co-operation in science and technology since the post-World War II period. International STI co-operation – as in other policy domains – is based on national interests, enabled by shared understanding and common values. This is an important principle to consider when discussing the contribution of STI in international co-operation to address grand challenges.

A second principle borne out of the first is the principle of reciprocity that is central to relations between sovereign nation states. Reciprocity in scientific co-operation implies that co-operation should be mutually beneficial even if there may be asymmetries or equivalences in the capacity of research partners or developing countries to co-operate.

A third principle is that for countries to be able to co-operate in STI, their national innovation systems must be strong. Consensus on the need for international co-operation remains fundamental in the hands of the nation-state while the strength of ability to implement co-operation relies on strong research institutions such as ministries, funding councils, universities, and public research organisations as well as good governance arrangements.

There are many other specific determinants of international STI co-operation between countries ranging from administrative and bureaucratic barriers and national security regulations to immigration legislation and (non-) recognition of foreign diplomas. These barriers and differences in national institutional arrangements create cross-border transaction costs and uncertainty that can hold back advances in science as well as innovation. International STI collaboration for the grand challenges are subject to specific barriers (see section 3.4).

Chapter 1 of this paper argued that **rationale for international STI collaboration for the GPGs has to be revisited to recognise the nature of the GPGs and the urgency of many global environmental and social challenges.** It put forward the following arguments for international STI collaboration:

- Developing international incentive regimes to address the GPGs: Domestic and international markets are not designed to incentivise provision of the GPGs or to prevent the negative social and environmental impacts of growing consumption and production;
- Strengthening global STI potential: Providing systemic solutions for societal challenges exceeds the capacity of single states or any other actor;
- STI deployment capacity: Concerted co-operation is essential to deliver solutions in acceptable timeframes to avoid approaching environmental tipping points or to be able to respond in times of severe societal crises;
- Higher STI investments: There are major problems to scale up necessary investments;
- Sharing risk and costs of experimentation to explore alternative innovation pathways.

For the purpose of the review of current practices conducted in this section, we distinguish between three forms of international STI collaboration considering stakeholders involved in collaboration:

- Co-operation involving public research sector actors (i.e. universities and public research organisations) and formal and informal networks of researchers and scientists, sometimes involving NGOs;
- Co-operation between companies, including multinational enterprises (MNEs), taking the form of technology co-operation agreements, cross-licensing and sharing of intellectual property, and joint research ventures;
- Hybrid co-operation involving companies as well as public research actors (e.g. universities or public research organisations).

The chapter first focuses on international research cooperation (section 3.2). It then highlights key issues in international STI collaboration in the private sector (section 3.3). It then addresses the emerging areas and issues of international STI collaboration for the SDGs (section 3.4) and concludes with key findings (section 3.4).

3.2. International research co-operation

The landscape for international co-operation in science and technology involving national governments and public sector actors is varied and diverse (see Table 3.1).

Table 3.1. Landscape of international STI co-operation among scientific organisations or between governments

Type of research	Individual scientists	National performing Institutions (e.g universities & PROs, national labs)	Dedicated Research funding via ODA ("Development Research")	Global Challenge Research Funds	Bilateral and Inter-governmental initiatives (Horizon Europe)	European Research Council Grants	International Networks of Research Funders & Performers (CGIAR)	International scientific organisations (CERN, ITER)	International organisations with STI mandates (IEA,NEA WHO, IPCC)
Basic Research	X	X			X	X		X	
Applied Research		X	X	X	X		X		X
Bottom- Up	X				X	X			
Top-Down		X	X	X	X		X	X	X
Supply-led	X	X	X		X	X	X	X	X
Demand-led		X	X	X	X				

Source: OECD (2018c)

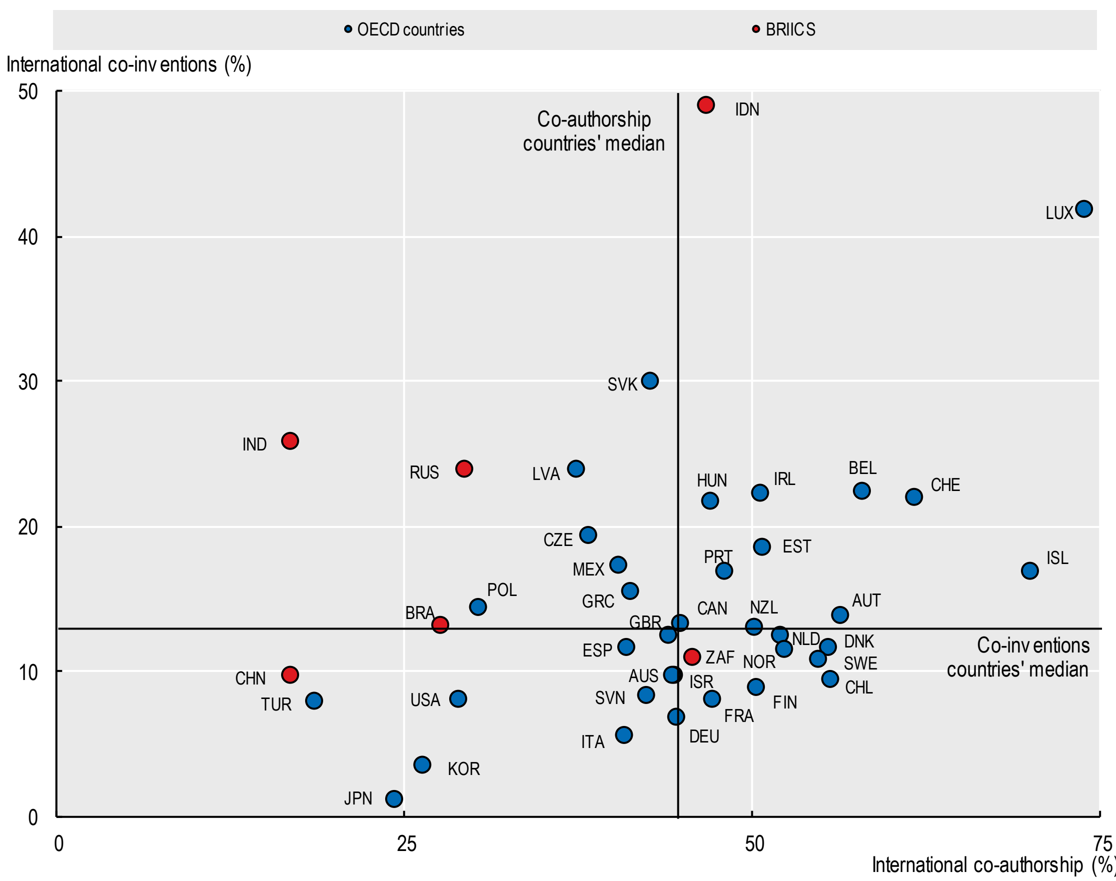
International scientific co-operation is primarily driven by "bottom up" priorities of individual researchers, research organisations and governments. While the culture and structures of the scientific enterprise (notably its openness to receive review from "peers", whether from home or abroad) are receptive to international co-operation, scientific research is much less internationalised than technology or innovation for the simple reason: most public funding for scientific research comes from national sources, and national ministries tend to fund national research organisations and national universities.

That being said, scientists do co-operate (and compete) internationally as evidenced by the rise in the number of internationally co-authored publications. International co-operation in science and innovation has increased sharply as illustrated by co-publishing and co-patenting trends. In general, countries display higher rates of collaboration in research than in innovation. Small open economies are however active in both scientific collaboration and innovation (Figure 3.1). OECD data show that over the 2005-15 period, international collaboration on scientific research intensified on a worldwide scale. China almost doubled its collaboration rate, albeit from a very low base. In 2015, (OECD, 2017a).

Some research fields are more open to international co-operation than others. Some scholars have postulated that subject-specific cultures affect collaboration patterns and spatial dependencies (Hennemann, Rybski, & Liefner, 2012). Research scientists have their own rationales for international co-operation which differ between, for example, natural and social sciences. At the institutional level, higher education institutions and public research labs such as Germany's Fraunhofer institutes have also adopted internationalisation strategies to tap into new knowledge networks and to attract and exchange talent. A useful indicator of the quality of national university systems is their ability to attract foreign students seeking a top-flight graduate education. In this area, as in others, the pressure of international competition appears to be triggering efforts in a number of OECD economies to undertake reforms to attract foreign research talent.

Figure 3.1. International collaboration in science and innovation, 2005 and 2015

(co-authorship and co-invention as a percentage of scientific publications and IP5 patent families)



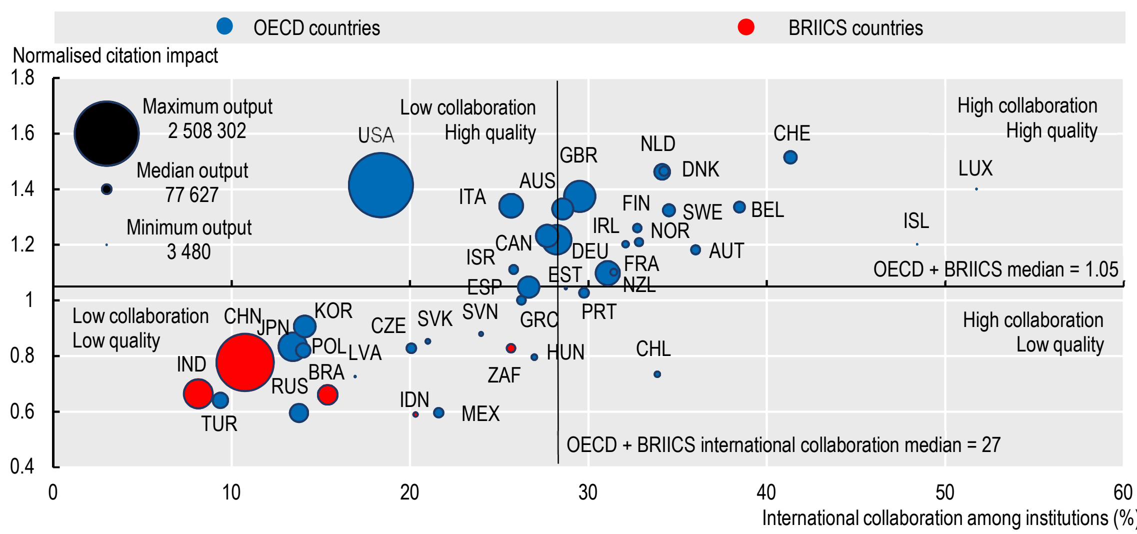
Source: (OECD, 2017a)

Another feature of scientific research that may influence the propensity to internationalise is that some research fields have a more direct impact (for a variety of reasons that are outside the scope of this paper) on technological development and in turn on productivity and economic growth. Again, economic competitiveness goals remain one of the priorities for funding public research and does not always favour international collaboration.

Evidence shows that stronger international collaborations clearly have a positive impact on the overall performance of national research systems, however. Measures of scientific research collaboration and citation impact (a quality measure of scientific publishing) at the country level are positively correlated, especially for economies with lower levels of scientific production. These smaller economies attempt to overcome their limited scale by participating more intensively in global networks. (Figure 3.2) (OECD, 2017).

Figure 3.2. The citation impact of scientific production and the extent of international collaboration, 2012-16

(as an index and percentage of all citable documents, based on fractional counts)



Source: (OECD, 2017a)

3.3. International STI collaboration in the private sector

In contrast to international STI collaboration in the public research, international co-operation in the business sector is entrepreneurial and market-driven. It is a well-established fact of market-based economies that competition drives innovation. However, it is an equally, and empirically, established fact that in their drive to innovate, firms have an incentive to engage in co-operation with other firms or public research organisations at various stages and levels. This is true both at the national level and at the international level.

In the case of multinational enterprises (MNEs), international collaboration often reflects a process whereby companies rely on research and innovation facilities located in several economies to draw upon geographically dispersed knowledge and/or develop complementarities with foreign inventors. The degree to which inventors collaborate internationally may be shaped by a wide array of factors, including the structure of the company or institution they belong to, the technology domain of the inventions, as well as language or cultural proximity.

Although the majority of R&D investments are still concentrated in companies' home country, the internationalisation of R&D has increased. The phenomenon is closely linked to the development of international trade and global value chains. Indeed, the rationale for international business R&D mainly follows market demand-side motivations, such as locating R&D with foreign production to tailor production to user needs as well as supply-side consideration, such as tapping into new talents and knowledge across various networks. Firms, universities, research institutions and government agencies are connected in "global innovation and research networks".

The knowledge sourcing and strategies of firms (whether through co-operation, acquisition of start-ups or competitors or joint ventures) are affected by a wide range of national policies, such as regulatory framework (e.g. on intellectual property rights protection), economic policy instruments (i.e. on foreign direct investment, corporate tax rates), availability of skilled workers, and institutional factors (such as dynamic relations between industry and universities) (OECD, 2017). A first reason to invest in S&T abroad is to customise technologies developed in the home country to fit local conditions. In this case, innovation and R&D are largely adaptive in nature. Motivations to decentralise this type of innovation are primarily demand-oriented and related to market proximity as that they need to be close to "lead users" and to adapt products and processes to local conditions.

A second and more recent type of S&T investment abroad seeks to obtain access to foreign knowledge and technology. Innovation strategies increasingly rely on global sourcing to tap into new S&T trends worldwide and to develop new ideas that can be implemented around the world. This also explains the trend towards open innovation, whereby firms seek partners for collaboration on R&D and innovation. Location factors for these investments are more supply-driven and are affected by factors, such as the host country's technological infrastructure, the presence of firms and institutions with benefits that investing firms can access and absorb (e.g. to trained personnel and established links with universities or government institutions), and the existence of appropriate infrastructure for specific kinds of research.

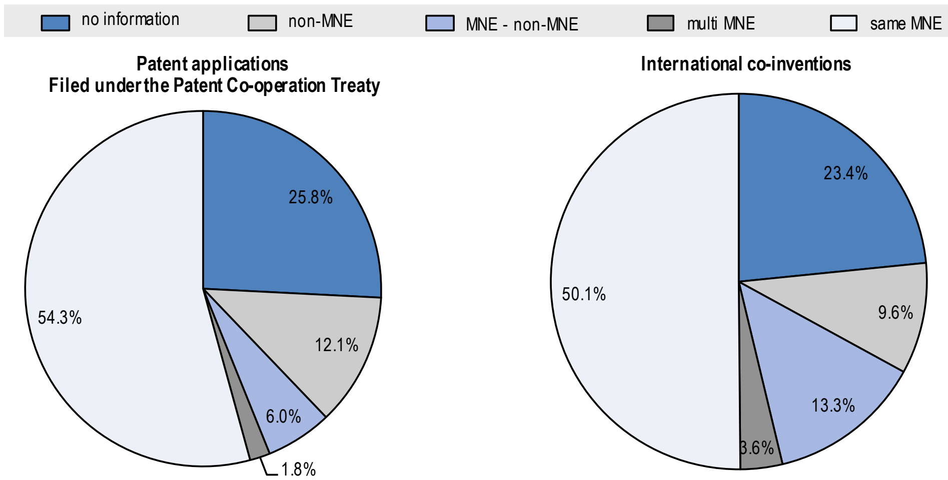
Through their growing investments abroad, MNEs play a major role in the internationalisation of R&D and innovation. More than 60% of all patent applications and two-thirds of co-inventions are related to multinationals' activities. Of co-inventions, more than 50% concern co-inventors in different countries but with the same multinational as applicant (i.e. headquarters and/or affiliates) (see Figure 3.3). While the majority of their investments in R&D are still concentrated close to MNE headquarters, foreign affiliates play an important role when they organise their R&D and innovation activities on a worldwide scale. MNEs have become central actors in the global innovation process, and, as a result, "national" innovation activities in host countries are significantly affected by MNEs' international location decisions.

Open access initiatives have a potential to narrow the gap in access to scientific and technological knowledge. Open access can contribute to dissemination of relevant data, methodologies and good practices, and support the development of STI infrastructures and platforms. It can also play a role in in overcoming financial and cultural barriers and accelerating interdisciplinary research and innovation for sustainable development (UNESCO, 2019).

The role of international investments for international STI collaboration

Attracting international investments in innovation is an important policy priority in emerging economies. Emerging economies have increasingly attracted international investments, including in STI. Changes in the investment behaviour of MNEs largely reflect the changing landscape of innovation and the increasingly global supply of S&T resources and capabilities (see Chapter 1). China and India, for example, with their growing capacity for research and innovation, are now important players.

Figure 3.3. The importance of multinational enterprises (MNEs) in patenting and international co-invention, 1995-2013



Note: The left-hand chart shows the shares of patent applications that can be allocated to one multinational (same MNE), several multinationals (multi MNE), multinationals and non-multinationals (MNE-non-MNE), non-multinationals (non-MNE) and those for which no information is available. The right-hand chart measures international co-invention by focusing on patents with multiple inventors who reside in different countries. It shows the share of co-inventions that can be attributed to same multinational (headquarters and/or affiliates), several multinationals, multinationals and non-multinationals, non-multinationals (non-MNE) and those for which no information is available.

Source: OECD (2017b)

The increasing competition from emerging economies for international investments – in both labour-intensive and innovative activities – has raised concerns in some advanced economies about their longer-term economic future. They question whether the relocation of major production and distribution investments by MNEs (including their own) may result in a loss of higher value-added activities, such as R&D and innovation-related activities, to emerging economies.

Governments typically use a mix of policies to attract international S&T investments. To be effective, the more traditional inward investment promotion has to be complemented by specific innovation policies. Because of the broad and pervasive character of innovation, countries draw on a broad range of policies. International investors carefully study the strengths and weaknesses of the underlying determinants of the locations under consideration and typically look for a package of attractive location factors and sound economic fundamentals. The design and implementation of a country's innovation policy depends on the (innovation) characteristics of the country. There is no "one size fits all" optimal set of policies for all countries/regions.

There is increasing policy competition among countries to attract international investment by offering individual investors direct incentive packages (e.g. subsidies and tax breaks, including R&D tax credits). Many countries and regions try to position themselves as attractive locations for S&T investments, often with investment promotion campaigns. Recent examples are: Research in Germany, Team Finland–Strategy for promoting foreign investment, and Essential Costa Rica. Japan External Trade Organization seeks to attract both R&D facilities and the Asian regional headquarters of global companies. National investment and export promotion agencies play a key role in these strategies by disseminating information, identifying and targeting prospective investors, and providing tailor-made investment services. A number of these programmes are developed in close co-operation with the business sector, such as the United Kingdom's Catalyst UK and UK Advisory Network initiatives. Many OECD countries (i.e. Australia, Belgium, the Czech Republic, Germany and Slovenia) offer new incentives, or have modified existing incentives, to invest in R&D and innovation, including tax incentives.

Almost all governments have sought to attract international investments in high-technology industries in one form or another, as these investments are generally believed to bring greater benefits to host countries, due to their large spillover effects. While differences exist across countries, industries commonly targeted are electronics and telecommunications, equipment, pharmaceuticals, aerospace, automotive (manufacturing) and business services and telecommunications (services). In recent years, in addition to this industry-based approach, countries increasingly consider the growing international fragmentation of firms' value chains and are taking a more functional approach by prioritising innovation, S&T, R&D laboratories, headquarters and other decision centres. A major challenge for governments is to design policy instruments that are open to MNEs, but at the same time optimise the benefits to the domestic economy.

There is evidence suggesting that policy incentives may divert investments from one country to another within a geographic region. While there is not yet conclusive evidence that competition to attract international investment has systemic negative effects, policymakers should remain vigilant about potential adverse consequences. Furthermore, spillovers from MNEs do not occur automatically and complementary measures are therefore necessary to increase the absorptive capacity of domestic firms for the advanced technology of MNEs.

3.4. Emerging areas and issues of international STI co-operation for the SDGs

One aspect on international STI co-operation that has been less studied is the issue of how governments and the various actors involved (i.e. ministries, national research funding councils, public research organisations, universities and national labs) effectively prioritise, finance and implement international STI collaboration with the explicit objective of addressing grand challenges such as climate change or those in the SDGs.

Grand challenges are broadly defined as persistent, complex and large-scale problems facing humanity. They require science and technology co-operation to solve them because no single country can solve these problems alone (OECD, 2012). Many of these grand challenges are related to long-standing problems of human health; the environment; and a lack of economic development more generally. They require knowledge from many scientific disciplines and a range of government, private and civil society actors to pull human, financial and infrastructural resources to work together.

Emerging landscape of international STI collaboration for the SDGs

The emerging landscape of STI collaboration for the SDGs needs to integrate development and innovation policy as well as include new actors and founders, such as the charities and foundations financing development and research activities related to the grand challenges.

Stepping up efforts for international STI collaboration for the SDGs, especially with developing countries, requires important changes to the current system for international STI co-operation. Recently, the EU has adopted an "Open to the World" policy with a view to expanding its co-operation with third countries. The UK has been at the forefront of efforts to increase research funding for ODA and many other countries have made this issue a priority.

There is growing recognition in the Official Development Assistance (ODA) community that investment in research and innovation are essential to meet the SDGs. To some extent, capacity building in research has long been promoted by OECD Official Development Assistance agencies with a focus on poverty reduction, education, agriculture, and health for example. Over the past decades, the discourse in aid agencies has evolved to promote innovation, including social innovation, so that institutional capacity can be created in countries to sustain research capacity across more sectors of the economy

It should be kept in mind that there are important differences in how the grand challenges are viewed from the perspective of developing countries versus developed countries. Some observers have pointed out that the meaning of "environmental" or climate priorities differs in the case of developing countries. Environmental problems like biodiversity are clearly a global issue but at the level of a developing country that issue may come second to "local environmental challenges" issues like access to clean water and arable farmland. Several research councils in OECD countries are active in providing research funding for development such as Research Council of Norway, Swiss National Science Foundation (Programme for Research on Global Issues), and the Swedish Research Council (programmes to support development research).

In the UK aid funding include a significant portion of research funding (Figure 2.5), whether it is research that is used to support the operations of the aid agency or research to address development challenges. DFID has a research budget of a similar size to the Global Challenge Research Fund (GBP 390 million per annum over the next four years). The UK's Newton Fund, established in 2014, uses science and innovation to promote economic development and social welfare in partner countries. It matches spending by partner countries in the developing world with UK ODA funds, with a UK investment of GBP 735 million to 2021.

The entry of research funding councils and research ministries has led to some tensions such as what should be the balance between research focused on excellence and problem-driven research focused on providing solutions to developmental challenges. Furthermore, the immediacy of goals like the SDGs requires more applied research and solutions as opposed to longer-term research projects.

Major research charities such as the Bill and Melinda Gates Foundation, the Wellcome Trust are not only engaged in funding research and education for the grand challenges, but they also collaborate with research funding councils and research ministries in OECD countries to develop public-private partnerships to implement the co-operation.

International organisations, such as the WB, WHO, UNEP, the European Commission (EC), are also involved in areas from agenda setting, funding and supporting training and capacity building at international level (e.g. Horizon 2020, co-funding through European Research Area Networks (ERA-NETs) and ERA Net+ as well as Joint Technology Initiatives). The International Energy Agency (IEA) has a mandate to promote international collaboration in the area of renewable energy and energy efficiency and supports various networks with this aim, including the "Clean Energy Ministerial"- a regular meeting of high-level officials, responsible for promoting clean energy. Global networks, such as the Belmont Forum, which is a partnership of funding organisations, international science councils, and regional consortia that fund research partnerships based on competitive call co-developed a mix of scientist and stakeholders from at least three countries. The Future Earth Initiative federates research projects and other initiatives related to global environmental change.

See Annex IV for case studies of international STI collaborations, addressing global societal challenges.

What drives and hampers international STI collaboration for the SDGs?

Despite the increase in international STI collaboration globally as measured by scientific co-authorship and co-invention data, much of the collaboration remains motivated by scientific agendas of scientists, public research organisations, and universities followed by government and business in terms of industrial, economic and scientific diplomacy and security considerations.

There is little multilateral collaboration in science and technology explicitly targeting the SDGs or the production of GPGs. The literature on international co-operation for the grand challenges has identified a number of factors holding back international co-operation and international co-operation for the SDGs (OECD, 2012 and 2018c):

- National research focus and the limited alignment between national STI governance frameworks;
- Global public-good problems with individual countries unwilling to pay the costs of action ("tragedy of the commons");
- Lack of knowledge of partners' capabilities, especially in developing countries;
- Lack of trust and legal regimes;
- Weak intellectual property rights (IPR) protection, especially in less-developed economies;
- Low government and business capacity in partner countries, including low number of researchers and lack of necessary research infrastructure to enable international co-operation;
- Fragmented bottom-up and non-state initiatives (e.g. universities, NGOs, foundations);
- Limited incentives for individual countries to provide the public good solutions that are necessary;
- Major problems in the scale of investment that is necessary and third, there are serious issues of technological uncertainty that require multiple search paths to be explored.

In general, governments tend to co-operate under principles of reciprocity or win-win scenarios where they can identify direct and near-term benefits in terms of social, economic, technological or competitiveness. In some cases, collaboration between states may be motivated by wider motivations (e.g. science diplomacy and geo-political strategies), and the implementing actors are then encouraged to determine the modes and scope of co-operation, which may be less or more ambitious, depending on the context and balance of negotiating power between the actors/agents.

International collaboration in STI suffers from fragmentation, notably as regards the bottom-up national initiatives. This is even more so the case for the "grassroots" spontaneous initiatives of researchers themselves, which may actually face barriers to development (e.g. visas/work permits for researchers, and/or purely national grant schemes, which do not allow financing of international projects).

Another major barrier to mobilising STI for grand challenges and the SDGs concerns the historical disconnect between policy communities responsible for promoting development through ODA and the mainstream science, technology and innovation policies. The development community, including multilateral aid agencies traditionally focused on helping developing countries improve primary education, reduce poverty and infant mortality and improve agricultural productivity. Advanced research capabilities, higher education and researcher training, and the use of frontier technologies were not priority areas for development aid agencies until fairly recently.

Finally, there is the issue of research collaboration with developing countries. Research projects for development often aim to promote diverse goals such as scientific excellence, social impacts and capacity building but these goals may not only be difficult to achieve on their own and involve trade-offs, they may also require different evaluation frameworks and targets.

3.5. Key findings and lessons learned

The present system of international STI co-operation is not well equipped to cope with the grand challenges and to effectively address the SDGs. The key findings and lessons for the new goal-oriented framework of international STI collaboration include:

- There is a need to link national research agendas and international priorities, notably the SDGs. Grand challenges are both local and global. Many countries such as Japan, Brazil and France are now seeking to align their national and international STI strategies with the SDGs for example. This implies new governance structures to enable cross-ministerial collaboration as well as effective interfaces between line ministries, development aid agencies, and trade and foreign ministries.
- Developing countries need both absorptive and creative capacities to be able to absorb existing technology and develop their own innovation based on indigenous and external knowledge. International STI collaboration for the SDGs needs to strengthen local STI capacities to underpin the global transitions to sustainable development and environmental sustainability.
- New challenge-led funding models allowing for scaling up investments are needed. The existing models of international STI collaboration are not designed to attract finance on the level sufficient to address global challenges and GPGs.
- Multi-actor STI collaboration is needed. Whereas traditional scientific collaboration involved collaboration among scientific organisations or between governments, the SDGs require engagement with a broader range of stakeholders including companies, charities, foundations and civil society groups, as well as other previously excluded groups, that can produce knowledge and apply innovative solutions locally and globally. These new collaborations can foster new types of innovations that dominant actors alone would not create and help ensure that the innovations created are widely acceptable and can diffuse more rapidly in society.
- ODA should be linked to STI policies. While international research collaboration through ODA activities has increased in some countries, such as the Germany, Japan, UK, and the United States, total financing for research and technology through ODA remains low in absolute terms (around 5%, according to OECD estimates; around 10% among the top five donors, according to WB). Increasing investments in STI-related ODA, along with its measurement in line with global standards, should be an important element in national and international efforts to accomplish the SDGs.
- International STI collaboration should be designed to consider systemic interdependencies between the SDGs and potential trade-offs between policy interventions. To anticipate these interdependencies of governments, funding agencies and partners need to ensure greater interdisciplinarity in the collaboration projects.
- International STI infrastructures should not only advance scientific knowledge, but they should also promote innovation for the SDGs. This implies ensuring the knowledge and publicly funded data from such research infrastructures can be diffused more broadly to the local research communities and firms, enabling them to innovate and apply appropriate technologies to local problems.
- Differences in the regulatory environments and rules regarding researcher mobility and IPRs can nonetheless create barriers to international STI co-operation for the grand challenges just as they do in the case of international scientific collaborations.
- Wide range of impact indicators are needed to measure impact of international STI collaboration for the SDGs. Traditional research excellence dominates indicator systems for international STI collaboration. Societal and environmental impacts need to be integrated into impact assessment.

4. Fostering international STI collaborations for the SDGs

The evidence and findings of the previous chapters suggest that the present system of international STI collaboration is not well equipped to effectively address global challenges and the SDGs. There is a need to align the global innovation system with the overall ambition of the Agenda 2030. This implies revisiting many existing forms of international STI collaborations and forming new global partnerships capable to harness benefits of STI to respond to the major global challenges. This chapter discusses how to design international STI collaborations to respond to the scale and urgency of the SDGs more effectively.

The chapter draws on previous sections and focuses on lessons learned from existing international STI collaborations for agenda and priority setting, collaboration mechanisms and instruments, governance and institutional setting, funding models as well as monitoring and evaluation approaches relevant for international STI collaborations addressing the SDGs.

4.1. Towards a new frame of international STI collaboration for sustainable development

Innovation is not only technology: towards a systemic understanding of innovation for the SDGs

The innovation challenge facing the international community today is to harness benefits of STI so to enable and accelerate the global transition towards sustainable development. The global, complex and interconnected nature of the SDGs require tapping into knowledge and creativity from across scientific disciplines, societal groups and economic sectors. International STI collaborations addressing the SDGs need to be based on a reflection on which modes of science, technology fields and types of innovation are likely to become drivers of sustainability transition in different economic, social and cultural contexts around the world.

There is a need for innovations which do not only answer to existing market demand but respond to current and emerging societal and environmental needs which markets often ignore or create in the first place. Innovations with potential benefits for the SDGs are diverse. They include new technologies and products, process and organizational improvements, social innovations but also more systemic changes in socio-technical systems, such as energy or transport, which often require changes in many countries (e.g. innovation value chains). Such innovations need to challenge dominant business models, redesign entire functional systems, change urban and rural landscapes, and advance new governance and policy frameworks (Geels, 2002, 2004; Steward, 2008; OECD, 2015). They require new forms of international STI collaboration.

International STI collaborations for the SDGs: beyond scientific excellence and economic growth

The global challenges, because of their complex, interconnected and uncertain nature, force STI policymakers to reflect on national development objectives in the context of global processes and Global Public Goods. This requires new forms and new quality of global STI collaboration bringing together multiple stakeholders.

Innovation for the SDGs requires that policymakers adopt a broader view of the benefits of international STI cooperation that include not only economic benefits but also public good benefits and benefits in terms of facilitating system transitions to achieve national sustainability. Policymakers also need to adopt a longer period in evaluating the impacts of innovation for grand challenges.

There should be collective arrangements for the distribution of direct costs and private benefits that may accrue. The increasingly globalised nature of innovation provides an additional rationale for international STI collaborations for the SDGs. The geographical configuration of innovation systems has become increasingly complex, spanning actor networks and institutional contexts across borders. Thus, for example, the ongoing transition to renewable energy in Germany, China and the UK should be seen as a co-evolutionary dynamic between innovation actors in all these countries that together form a new emerging global innovation system (Fuenfschilling & Binz, 2017). These findings suggest that the ability of countries to meet their own national challenges can be enabled and strengthened by international co-operation.

Aligning national STI strategies and policies with the SDGs

Governments need to re-assess their national STI strategies with a view to connecting them with the SDGs and wider international STI agendas. The present system of international STI co-operation is not well equipped to cope with the grand challenges and address the SDGs. The international collaboration mechanisms in place favour basic research and the strengthening of national research systems over challenge-oriented research and innovation addressing internationally shared development goals. The direction of international co-operation in research remains primarily driven by "bottom up" priorities of individual researchers, research organisations, even if a number of collaborations on climate change, global health, renewable energy or sustainable agriculture are initiated via "top down" processes.

Reframing domestic policies to consider global challenges is crucial for international STI collaboration; evidence suggests that the most effective collaborations are those with a close alignment with the domestic policy agenda of key partners (OECD, 2012). Governments need to consider new funding instruments and foster new partnerships and governance arrangements to connect national efforts with co-operation on the grand challenges.

Stepping up efforts for donor countries to co-operate in STI among themselves and especially with developing countries will require important changes to the current regime for international STI co-operation. Although research funding agencies have a great deal of expertise in funding excellence-oriented international collaborative projects, they are less well equipped to fund and organise collaboration to address grand challenges and the SDGs, especially involving developing countries. This is partly because of institutional missions that prioritise research excellence over other goals. In addition, mobilising STI to address grand challenges requires more than research funding; it requires more understanding markets and business innovation processes. It also requires investment in hard and soft infrastructures such as entrepreneurial capacity to convert research findings into practical solutions.

Many countries have already stepped up R&D investments in health and environment. Within the EU, framework programmes have helped link national objectives to Community-wide objectives in order to strengthen the creation of a European Research Area (ERA) and boost the region's research and economic systems. However, the SDGs require co-operation outside EU and OECD countries. Despite the rise of the BRICs, international co-operation is still concentrated within and among OECD countries.

Mission oriented innovation policies could potentially offer an opportunity to link efforts on national challenges and competitive strengths with efforts to develop common solutions to shared challenges. However, mission-oriented innovation policies represent, a priori, a greater opportunity for international co-operation among countries with shared strengths than with developing countries, who lag behind advanced countries in terms of both research capacity and innovation potential.

Towards a new paradigm of transformative international STI collaborations for the SDGs?

The success of future international STI collaboration for the SDGs will require a transition from competition to co-operation as the underlying principle informing innovation policy and behaviour. Innovation policy globally is dominated by the national innovation system model that aims mainly to strengthen and enhance the productivity of existing innovation systems within national boundaries. It is predominately based on a competitiveness framework whereby countries compete for competitive advantage by attracting investment, enhancing human capital and engaging in competitive innovation to deliver economic benefits in terms of jobs, exports and growth. This competitiveness framework proved advantageous in terms of increasing productivity and encouraging innovation.

The unprecedented complexity, scale and urgency of many challenges facing the world call for a different model of international STI collaboration. Innovation for the SDGs needs to address problems that individual countries cannot solve acting alone and solutions are needed urgently if we are to avert severe environmental and societal consequences. Competition under such circumstances must be balanced with co-operation in order to pool expertise, reduce duplication of effort and waste of resources, and find solutions within periods commensurate with the threat.

Achieving the SDGs will require a variety of innovations with an accumulated transformative potential to reconfigure systems of production and consumption. These "innovation mixes" will need to combine short-term deployment of tested technologies with more disruptive system innovations seeking longer-term impact. Such a systemic approach to innovation calls for a concerted international effort engaging various stakeholders from business, research and governments, operating at different levels of governance. It requires long-term patient investments in STI with an ambition to develop and deploy innovation for transformative impact (Mazzucato, 2017; Schot & Steinmueller, 2018).

When reflecting on innovation for the SDGs, it is key not to forget to place the emphasis on resolving problems in their specific local contexts rather than simply aiming at introducing most technologically advanced novelties. In many cases most effective innovations may be building on well-established technologies or social innovation based on indigenous knowledge. The specific challenge for developing countries is to build stronger capabilities and enabling environments to absorb and diffuse existing knowledge and technologies while building their own innovation culture that nurtures local knowledge and tap in entrepreneurial eco-systems. International STI collaboration can make a considerable contribution to this process by supporting endogenous innovation potential in developing countries and by strengthening their capacity to exploit external finance, knowledge and innovation.

4.2. Drawing lessons for international STI collaborations for the SDGs

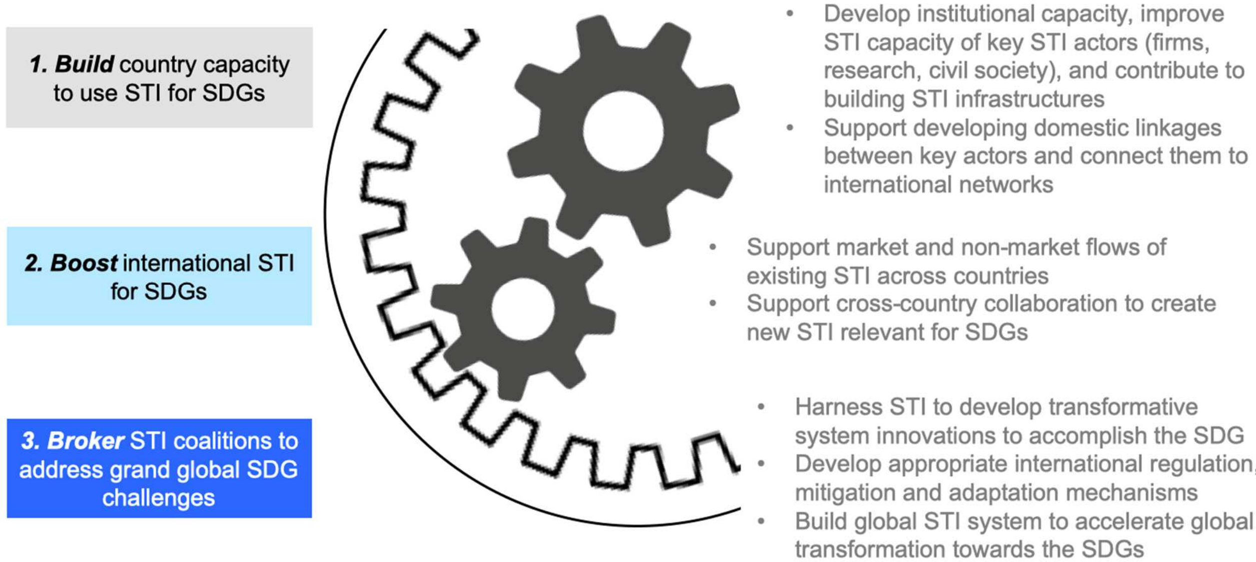
4.2.1. Three pillars of international STI collaboration for the SDGs

In order to capture various dimensions of international STI collaboration for the SDGs, this paper proposes to consider three pillars (see Figure 4.1) of international collaboration:

- Pillar 1: Building up national STI capabilities to address the SDGs;
- Pillar 2: Boosting international knowledge and technology flows for the SDGs;
- Pillar 3: Brokering international STI collaborations for the SDGs.

The first pillar focuses on strengthening national STI capabilities, mostly of developing countries, to address challenges underpinning the SDGs. This includes building both endogenous capabilities as well as capability to absorb external knowledge and technology. Collaborations under this pillar benefit directly individual countries. The support may be provided by another country (bilateral collaboration), group of countries or international organisations. This is the most common objective of international STI collaborations channelled through bilateral and multi-lateral ODA (e.g. UN system or WBG).

Figure 4.1. Key objectives for three pillars of international STI collaborations for the SDGs



Source: (IATT, 2019)

Strengthening national innovation systems and building sustainable sociotechnical systems in developing countries is necessary to achieve global environmental sustainability as set out in the Paris Agreement and achieve the broader sustainable development goals set out in Agenda 2030. Any well-functioning innovation system needs to be connected internationally to enable the flow and development of knowledge, skills and innovation (Ockwell & Byrne, 2016). Financial support for technology transfer to developing countries will, therefore, have limited impact on environmental or broader sustainable development goals unless dedicated policies aimed at strengthening capacities within developing countries are also in place. Developing countries need absorptive and creative capacities to adopt existing technologies and develop their own innovations. In this context, international co-operation in STI for the grand challenges is necessary to strengthen local capacities and accelerate the global transitions to sustainable development and environmental sustainability.

The second pillar focuses on boosting international flows of relevant knowledge and technology across countries and on supporting cross-country STI collaborations addressing the SDGs. The focus of international collaboration is to shape international STI markets and removing bottlenecks impeding the flows of knowledge, people, and finance directed towards the SDGs. The focus of international collaboration on this level is to adapt international framework conditions to foster STI for the SDGs. As a result of this intervention knowledge, people and investments relevant for the SDGs will reach countries and communities where they are most needed more effectively. This pillar is relevant for supplying GPGs needed for achieving the SDGs, such as data, expertise and scientific knowledge.

There are many good examples on this pillar, notably on global data sharing initiatives (e.g. the Group on Earth Observations or Malaria Genomic Epidemiology Network), open science platforms (e.g. F1000-Research, CODATA, Research Data Alliance, Sustainability Coalition for Open Science Services, European Open Science)[12] or international platforms dedicated to sharing good practices of innovations or

[12] UNESCO is leading the development of a UNESCO Recommendation on Open Science which aims to reach a global consensus on relevant top issues of concern (UNESCO, 2019).

technologies relevant for sustainable development (e.g. the ASEAN-India Innovation Platform). The ASEAN-India Innovation Platform focuses on innovation with societal relevance (Government of India, 2019). The platform focuses on product innovation, social innovation and research innovation. The platform supports networking activities connecting innovators and innovation intermediaries from the region to share good practices, improve understanding of innovative business models and support technology transfer and commercialization of research results. The focus is in inclusive innovation, including low cost technologies, with a potential to bring social impact and address challenges of inclusive growth. It develops "innovation bank" with information on open-source innovations and technologies and expired and abandoned patents. The platform also runs challenge awards for innovations addressing social and environmental problems in the region such as waste management and reduction of non-recyclable waste (see Annex IV).

The third pillar focuses on engaging in international collective STI actions with an ambition to tackle global challenges, notably the GPGs. The level of intervention is focused on enhancing the global STI system to endow it with collective capabilities and institutional settings to undertake collective action at a sufficient scale to face global challenges. These collective STI actions have an explicit focus on tackling global and achieving transformative impact. This level is key to safeguard the Global Commons (common pool resources) as well as to collectively develop new knowledge and solutions to accomplish the SDGs. The focus is on the planetary STI capabilities.

Whilst there are examples of major scientific collaborations mobilising scientists around the globe, such as notably the UN Intergovernmental Panel on Climate Change (IPCC), there are fewer examples of international collaborations focused on collective action on developing and deploying transformative innovations, tackling global challenges, such as supplying the GPGs underpinning many Global Goals. One notable example of a long-standing major international STI collaboration addressing sustainability challenges are European Union's multiannual Framework Programmes. Horizon 2020 programme (2014-2020), for example, includes a pillar dedicated to resolving major complex societal challenges (EC, 2019). The upcoming "Horizon Europe" programme (2021-2027) follows a mission-oriented approach strongly focused on sustainability and emphasises the key role of international scientific collaboration for achieving the SDGs (EC, 2017). Although the programme is open to international scientific collaboration, it does not provide funding for joint international collaborations on transformative innovations addressing the GPGs.

There is a number of challenge-led global STI collaborations with an ambition to become pillar 3 type of initiatives. One example is "Mission Innovation (MI)" which is a global initiative launched in November 2015 at COP21 in Paris with an overall mission "to reinvigorate and accelerate global clean energy innovation with the overall objective to make clean energy widely affordable" (Mission Innovation, 2015). MI groups 24 countries and the EC. The main goal of the initiative is "to accelerate the pace of clean energy innovation to achieve performance breakthroughs and cost reductions to provide widely affordable and reliable clean energy solutions that will revolutionize energy systems throughout the world over the next two decades and beyond." One of the key actions of Mission Innovation is facilitation of multi-lateral research and innovation partnerships focused on innovation challenges "in technology areas that could provide significant benefits in reducing greenhouse gas emissions, increasing energy security and creating new opportunities for clean economic growth" (see Annex IV for more details).

Another recent example is the Global Antimicrobial Resistance Research and Development Hub (Global AMR R&D Hub) launched in May 2018 (Global AMR R&D Hub, 2018). The establishment of the hub was led by the German Federal Government in the framework of Germany´s G20 presidency in 2017. The hub brings together 16 countries, the EC, two philanthropic foundations (Bill & Melinda Gates

Foundation and Wellcome Trust) and four international organisations (as observers). The Hub aims to become a key actor with an integrating role in global R&D on AMR by bringing together governments and relevant foundations from different world regions, promoting the focus on AMR as one of the global R&D priorities and promoting high-level coordination and alignment of existing public and private funding to leverage investments in R&D on AMR on national and international levels (see Annex IV for more details).

Engaging in international STI collaborations is easier for countries with strong STI capacities. Table 4.1 puts forward key considerations on international STI collaboration for developing countries, notably for the least developed countries with limited institutional capabilities and underdeveloped STI infrastructures.

Table 4.1. International STI collaborations for the SDGs in developing countries

Pillars	Considerations for developing countries
Pillar 1: Building up national STI capabilities to address the SDGs	- Because the NIS is particularly weak in developing countries, strengthening all these elements, particularly human capital is very critical - Developing countries are also quite weak in the framework conditions, so policy advice for reforms in this area is also quite important - Strengthening STI capacity to use STI for SDGs is particularly challenging for developing countries given their larger SDG, STI, and funding gaps; so more concentrated international assistance in this area is warranted
Pillar 2: Boosting international STI flows for the SDGs	- Developing countries may requires special provisions regarding IPR policies toward data flows and new regulations - Developing countries would benefit from easier access to scientific and technical information - They also need greater capability to assess, access, adapt, and effectively deploy technology and innovations available from abroad - Developing countries need to strengthen the deployment part of their NIS to be able to take advantage of existing technologies and innovations, as well as new ones
Pillar 3: Brokering international STI collaborations for SDGs	- Developing countries need a stronger knowledge base for international collaboration for advances in STI - They need a stronger voice to articulate the demand for new STI inputs that can help them meet SDGs - There is a need to broker global coalitions to use STI to address special challenges more prevalent in developing countries such as communicable diseases, hunger, malnutrition, etc.

Source: Authors

Table 4.2 summarizes current practices of international STI cooperation in each of the three pillars. For Pillar 2 on boosting STI flows, the table distinguishes market and non-market mechanisms since they have different targets of support and instruments. The last column of the table gives illustrative examples of existing initiatives.

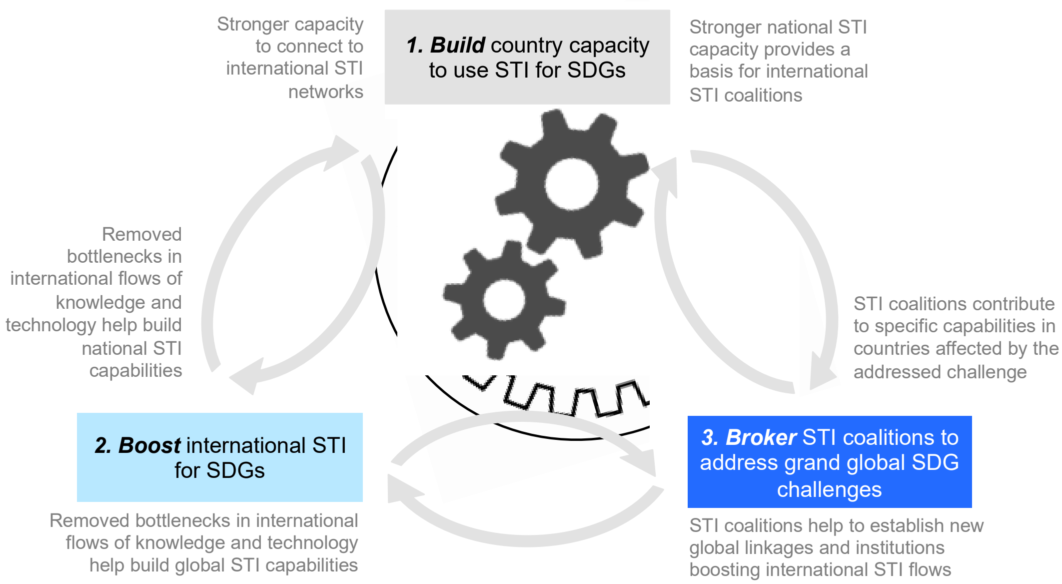
Table 4.2. Current practices of international STI cooperation for SDGs

		Unit of intervention	Areas of international support (instruments and recipients)	Selected examples
Build country STI capacity		Individuals	- Researchers: scholarships, research grants - Farms/firms absorptive and innovation capacity: training, business development service (BDS), agricultural/management extension services - STI policymakers: training, peer-learning, learning-by-doing	ASEAN-India S&T Development Fund
		Human capital base and institutions	- STEM education, digital skills, basic and applied research institutes - Entrepreneurship/deployment system, intermediaries, networks - Public service delivery (e.g. health, education, water, conservation…)	WB ACE UN agencies STI training programs
		Broader STI system	- STI-related infrastructure (quality systems, connectivity…) - STI system diagnostics, policy advice / assistance to reforms - Sectoral R&D and innovation systems (e.g. energy)	UNEP TNA UNCTAD's STIP reviews UNESCO's Go-Spin UNECE's innovation reviews WB's PER
Boost international STI	Non-market	Link / strengthen existing STI for SDGs	- University partnerships, exchange programs - Multi-stakeholder platforms, networks, communities of practitioners - Facilitate a multi-stakeholder collaborative approach to bring together efforts	UN Multi-stakeholder Forum on STI for SDGs WB PASET South African AOSP GEOSS
		Increase new STI for local challenges	- Supply-push: joint research projects - Demand-pull: government procurement, prizes	CGIARUK GCRF X Prize Horizon Europe Int'l Research Partnership GEO programs GFDRR projects
	Market	Barriers to markets	- Support the development and use of the online technology platform for match-making STI Supply and SDGs demands	Global AMR R&D Hub TFM online platform
		Trade and investment flows	- Donor/IFI projects to crowd in and catalyse R&D, technology transfer and innovation linkages through private capital and blended finance - Treaties and other agreements conducive to STI flows (e.g. IP)	WEF NVA, Grow Africa Lighting Africa US FtF, New Alliance WEF WRG
Broker STI coalitions		Norms, values, standards, statistics	- Global visions, strategies, monitoring reports - Cross-country monitoring and evaluation systems	UN Digital Cooperation Panel IPCC
		Coalitions addressing critical global gaps	- Partnership/funding/governance frameworks - Mission-innovation programs, grand challenges	Mission Innovation US PEPFAR WB DE4A CGIAR Partnerships and innovation
		Transformative STI system (global/regional)	- Joint or aligned fiscal/procurement/research policies - Explore synergies and promote system-wide leverage to support international partnerships and multi-stakeholder initiatives for the design and implementation of roadmaps	Joint Programming Initiatives (JPIs) Horizon 2020 TFM

Source: Authors

The three pillars, and their respective actions and collaboration mechanisms, are interconnected and interdependent. These interdependences are not linear or one directional (see Figure 4.2). For example, strengthening STI capabilities of developing countries alone will not overcome bottlenecks in the international STI flows and effectively address challenges of GPGs. Boosting international STI flows alone will not overcome capability gaps on country level. Taking international collective action will not replace building country level capabilities. On the other hand, however, improving international STI flows can directly help countries to build their domestic capabilities whilst investing in global STI collaborations can in some cases help developing countries to develop specific domestic capabilities which can, at the same time, solve their local problems and contribute to Global Commons (e.g. sustainable fisheries).

Figure 4.2. Interdependencies between three pillars of international STI collaborations for the SDGs



Source: Authors based on (IATT, 2019)

The analysed examples of challenge-led international STI collaborations all include instruments and collaboration mechanisms addressing more than one pillar of collaboration. For example, CGIAR includes dedicated activities aimed at building local capacity (Pillar 1), knowledge sharing e.g. via participation in multi-stakeholder platforms (Pillar 2) as well as facilitating integrated international collective actions addressing global challenges and global transformations (Pillar 3). Similarly, Mission Innovation includes information and knowledge sharing activities (Pillar 2) as well as international joint technology demonstration (Pillar 3).

How the pillars relate to one another depends on the specific challenge. For example, the joint global STI action for protecting oceans from plastic waste may be used as a strategic framework to concentrate international efforts to build specific capacities and infrastructures in specific countries that are a direct source of plastic waste (i.e. China and South-East Asian countries) while at the same time invest in collaborative efforts to address the roots of the problem (e.g. developing substitutes to plastic packaging and implementing international regulatory frameworks with incentives for new materials and penalties for illegal discharging of waste).

Given the complexity and urgency of challenges we face, countries and international community need to engage in three pillars of international collaboration to mobilise STI for Global Goals. The pillars should not be translated into a simple linear step-by-step strategy in which the collaborative effort needs to first focus on improving country capacities, then addressing international knowledge flows and then considering international collective action.

4.2.2. Governance and institutional settings

Key actors and participation

International STI collaborations addressing the SDGs should carefully consider the roles of various actors in national and global innovation system. Participation and outreach will depend on the nature of the challenge as well as on the policy and governance context of each collaboration. Given the complexity and interdependence of challenges underpinning the SDGs and the risk of capture, it is important to ensure that STI collaboration is based on a broad and active participation of stakeholders and supports information exchange and mutual learning to achieve common understanding and consensus between partners. Exclusive modes of governance are more vulnerable to capture as the interests of dominant donors or powerful groups can dominate the agenda (Mattli & Woods, 2009).

Traditionally, STI collaborations on this level engage governments (notably ministries of science and technology), scientific organisations and individual researchers. The focus on building national STI capabilities for the SDGs requires a systemic view on the role and capabilities of various actors across the innovation system, connections between them as well as the fitness of national institutional framework for challenge-led STI. Therefore, in order to build STI capabilities in a more comprehensive manner, the collaborations should open to other actors and actively engage private sector and civil society.

Addressing complex global challenges require sufficiently broad and deep stakeholder participation to ensure access to necessary resources, including information, knowledge and experience, as well as the representation of ethical and cultural perspectives of different actors from different regions. Stakeholder engagement is key to better anticipate and mitigate potential misunderstandings and conflicts caused by capture and exclusion of less powerful groups.

Industry involvement is key for putting R&D results into practice and communicating existing and expected market demand for STI for GPGs. Modes of international STI collaboration have to consider their interests, incentives, expectations and risk perceptions (OECD, 2012), notably in the context of their role in delivering GPGs or phasing out their operations, which contribute to "public bads." Partnerships should also consider roles of existing international and local STI leaders (e.g. incumbent companies) as well as niche actors proposing novel alternative solutions to the challenges.

Stakeholder engagement mechanisms have to consider the incentives and rewards, which are likely to motivate different stakeholders to engage and remain engaged in collaboration. The reward system needs to recognize that incentives of different stakeholders differ (e.g. access to information and knowledge, access to finance, ethical considerations, reputational rewards etc.). With the knowledge of incentives driving different stakeholders, the mechanisms can be designed to encourage (or discourage) different forms of participation. In case of particularly risky initiatives requiring early investments, it is important that the partners discuss how to share risks and benefits of the participation between first and later movers in a fair and transparent way.

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manner, the collaborations should be open to other actors and actively engage private sector and civil society.

Agenda and priority setting

The ambition and scope of the 2030 Agenda and the SDGs means that international STI collaborations should allow a wide range of societal groups to bring their interests, needs and knowledge to influence the framing of agendas and the choice of priorities. Involving a broad range of stakeholders in agenda setting is important to achieve a comprehensive picture of the global challenges at hand and ensure a wider buy-in from key actors.

Building shared understanding of challenges is key for creating trust between stakeholders, especially in case of newly created multi-stakeholder partnerships. It is important that stakeholders have a clear understanding of areas of existing and potential alignment as well as areas where their views and reward expectations may differ. Understanding the differences is key for developing a more realistic vision and pathways. The vision can be developed during visioning workshops and meetings. There are also established methods allowing to map similarities and difference in problem perceptions (e.g. multicriteria mapping).

Top-down exclusive approaches to agenda setting may increase the risk of capture. The risk of capture and vested interests are typical for international STI collaborations (OECD, 2012). Strong interests, often limited to national STI interests, are likely to skew the deliberation of priorities of international STI collaboration. Involving a diversity of stakeholders while balancing the competing interests of actors, countries and regions is therefore a key challenge in setting STI priorities for global collaboration and developing common overall objectives and priorities. Governance mechanisms, however, have to ensure that wide stakeholder involvement does not lead to an inefficient or inconclusive agenda- and priority-setting processes.

A combination of bottom-up and top-down approaches may help to ensure a balanced priority-setting process. Bottom-up approaches can help to ensure programmes that are demand-driven from a grassroots or micro level, while top-down approaches ensure that programmes are embedded in the larger picture of global challenges (macro perspective) with high-level political support at an early stage of an initiative (OECD, 2012).

The process of agenda and priority setting for the international STI collaboration priorities needs to consider the complex and interconnected nature of challenges underpinning the SDGs. Rather than focusing on one of the SDGs, international STI collaborations should strive to address "nexus challenges" or system transformations. Recognising the complex nature of societal challenges at the early stage of problem definition and priority setting is critical to avoid crude simplifications, which later may lead to undesired outcomes or wider rebound effects. Problem framing during the priority setting process may benefit using approaches developed by many ongoing research projects mapping interrelations between the SDGs, based on available scientific evidence (ISC, IIASA).

Institutional setting and coordination

International STI collaborations can rely on many institutional designs, ranging from informal collaborative networks to fully institutionalised collaborations, operating as independent international organisations. The choice of the form and level of institutionalization should be made considering advantages and disadvantages of various models. The design needs to consider benefits and limitations of more or less formal arrangements and more bottom-up or top-down governance mechanisms.

In practice, the design of new and revamping of existing collaborations can benefit from the variety of mechanisms involving both informal and formal arrangements, which may evolve over time, with informal governance mechanisms ensuring ownership and motivation in early formative stages, and more formal governance modes guaranteeing predictability and longer-term impact.

OECD (2012) suggested that informal governance, such as international networks or ad-hoc issue-driven initiatives, are often politically acceptable and are desired forms of international STI collaboration, charactarised by high flexibility and fast response mechanisms. On the other hand, informal governance does not guarantee stable and predictable institutional setting and may be more prone to capture. Therefore, institutional settings relying predominantly on informal models may not be most suitable for long-term and goal-oriented international STI collaboration. In the context of addressing complex challenges and the SDGs, the design of international STI collaborations may include both top-down coordinated actions (e.g. long-term collaborative R&D projects) as well as provide space for explorative bottom-up activities (e.g. social innovation and early stage technological innovation). The latter is about building enabling environment and capacity for learning, experimentation and bottom-up collaboration.

To address societal challenges involving both urgent needs as well as the pursuit of the long-term STI goal, it is important to develop mechanisms, allowing to respond to short-term needs without sacrificing long-term goals (e.g. provide continuous support to people suffering from malaria while working on developing the vaccine). One example of adaptable governance arrangements is the IEA's Bioenergy Implementing Agreement, which includes a discussion of emerging challenges at each meeting of the partnership and provides for an adaptable "living" strategic plan (OECD, 2012).

The institutional design needs to consider how to ensure a level playing field for all partners, in particular, by counteracting information asymmetries and differences in institutional capabilities between donors and beneficiaries, which may disadvantage actors from developing countries. One way to address this issue is to design the collaboration process as a collective learning process, based on: building a shared understanding of challenges and goals; agreeing on the common values, rules and mechanisms of collaboration; and creating a shared pool of knowledge informing the choices and focus of collaborative STI activities. Co-creating the institutional design may also reduce the risk of capture.

Funding models

Effectiveness of international STI collaborations depend on the well-designed and functional funding mechanisms. International STI collaborations rely on funding from many sources, including public and private funders, contributing to a different extent to their core funding or specific projects.

The key question is how to ensure sufficient and sustainable funding for international STI collaborations addressing the SDGs. Considering that addressing global challenges require combining multiple sources of funding from public and private sources (see Box 4.1 on blended finance), another question is how to design and manage funding models to accommodate diverse interests of international and national funders whilst avoiding the risk of capture and delivering on the ambition of the 2030 Agenda.

Table 4.3 summarizes key considerations for governance of international STI collaborations for developing countries, considering actors and participation, agenda and priority setting, institutional setting and funding models.

Box 4.1. The promise of blended finance

The OECD defines blended finance as the “strategic use of additional finance towards sustainable development in developing countries” (OECD, 2018b) and the IFC refers to blended finance as “a financing package comprised of concessional funding provided by development partners and commercial funding by IFC and co-investors.” Additional finance in the context of the OECD’s definition refers primarily to commercial finance. Blended finance is part of a broader “toolbox” of development finance tools that can be used to mobilise additional, and enhance existing, public and private finance for sustainable development.

One of the objectives of blended finance is to mobilise capital that would not otherwise support development outcomes by attracting commercial capital towards projects that benefit society while providing financial return to investors. Its potential lies in the ability to remove many bottlenecks that prevent private investors from targeting countries and sectors where additional funding is needed. (OECD2016).

For instance, several funds use a “cascade” approach where public actors provide “first loss” capital which serves as a catalytic risk buffer to encourage private investments. Specifically, on science, technology and innovation funds such as Deutsche Bank (DB)’s Universal Green Energy Access Programme (UGEAP) employ this approach (Morgado & Lasfargues, 2017).

The UGEAP aims to contribute to universal electricity access in sub-Saharan Africa over the next 15 years by scaling up capital from international private investors in renewable energy. The fund’s target investments fall into three categories:

- Off-grid green electrical energy (e.g. solar home systems)
- Green energy supply for mini/micro-grids electrifying communities and remote villages
- Green electrical energy supply to businesses.

The target countries are Benin, Kenya, Namibia, Nigeria and the United Republic of Tanzania.

Over the initial investment phase of 5 years, the UGEAP aims to raise USD 500 million in committed capital. The project’s anchor investor is the Green Climate Fund that contributes USD 80 million. UGEAP raised USD 300 million up to date in the form of equity investments, of which the other USD 240M are split as follows: USD 192.6 million from the private sector, USD 20 million from the public sector and USD 9 million from DB. USD 1.6 million are provided in the form of grants.

The fund aims to make around 50 investments, totalling a volume of USD 500 million in the course of the first 5 years. The program will focus on enabling local financial institutions to provide long-term loans to companies that will provide clean energy solutions. This program is expected to avoid 50 million tonnes of CO2 emissions over its lifecycle.

More generally speaking, the “Blended Finance Funds and Facilities: 2018 Survey Results” presented findings relating to the management, capital structure, investment strategy and portfolio allocation of surveyed blended finance funds and facilities. The 180 responses highlighted the great heterogeneity of central aspects and characteristics of blended finance funds and facilities. The asset under management ranges from USD 2 million to over USD 2 billion, with their aggregate total reaching USD 60.2 billion in 2017. (Basile & Dutra, 2019). 111 developing countries received investments. The bulk of blended finance goes primarily to energy and banking. Other sectors such as health, education, agriculture, water and sanitation appear at least in terms of vehicles targeting them.

Table 4.3. Considerations for governance of international STI collaborations for the SDGs

Mode	Actors and participation	Agenda and priority setting	Institutional setting	Funding models
Cross-cutting considerations	- Multi-stakeholder engagement from priority setting to monitoring and evaluation of international collaboration	- Consider the relevance of broadly understood STI in addressing societal challenges and the SDGs	- Institutional design ensuring organisational sustainability and level-playing field for all stakeholders	- Ensure broad alignment and scale-up of finance towards the SDGs
Pillar 1: Building up national STI capabilities to address the SDGs	- Engage local stakeholders to ensure that priorities of STI collaboration are shared and accepted by key communities	- Revisit development assistance to consider the role of STI in achieving the SDGs	- Build up and improving national STI institutional setting to better address local societal challenges and the SDGs	- Align country-level bilateral and multilateral ODA and other sources of funding (e.g. STI funds, development funds, private philanthropy) with the SDGs
Pillar 2: Boosting STI flows for the SDGs	- Improve international inclusion, engagement and coordination of key STI actors to remove bottlenecks to international knowledge and technology flows of relevance to achieving the SDGs - Ensure representation of underrepresented groups, communities and localities according to the "leave no one behind" principle	- Improve international consistency of STI agendas and priorities - Extend STI agendas and priority setting from the focus on science and research collaboration to better acknowledge the role of sharing applied knowledge and innovations	- Align and revise existing international agreements relevant for STI with the SDGs - Improve international collaboration and coordination of STI activities focused on the SDGs	- Streamline bilateral and multilateral ODA, FDI and other international funding mechanisms on the international level to address the SDGs more effectively
Pillar 3: Brokering international STI collaborations for the SDGs	- Build global STI coalitions and multi-stakeholder partnerships focused on global challenge and the GPGs	- Develop joint international agendas and strategies with shared priorities and targets for global STI initiatives and investments for the SDGsShift focus towards transformative system innovations with a potential to accelerate sustainability transitions	- Innovate existing and setting up new modes of global STI governance allowing for more coherent and synergetic STI investments and activities	- Establish global funding models catered for making and leveraging investments in STI addressing global challenges and the GPGs - Scale up of international blended finance funds (e.g. UGEAP), public innovation funds (e.g. Mission Innovation) or innovation challenge competitions (e.g. Hult Prize)

Source: Authors

4.2.3. Policy instruments and collaboration mechanisms

International collaborations can use diverse instruments and collaborative mechanisms supporting STI for the SDGs. The mechanisms range from high-level strategic policy exchanges and diplomatic dialogues to joining forces in co-designing and jointly deploying research and innovation instruments (see Table 4.4). What to consider when selecting and designing STI collaboration mechanisms and instruments to better address the SDGs?

The choice of instruments needs to consider the existing political and policy landscape, available resources (e.g. the costs of implementing different mechanisms are diverse) and existing STI capacity of collaborating partners (e.g. is there a need to build capacity prior to starting collaborative activates). Considering local needs and assessing existing STI capabilities is crucial in this context as it ensures fruitful engagement of all partners from the outset of the project. CGIAR's Capacity Development Framework (CGIAR, 2015), for example, considers capacity development an integral part of the impact pathways of research programmes, seeing it as a prerequisite for the programme's delivery.

Most international STI initiatives include more than one collaboration mechanism and combine mechanisms, allowing for policy dialogue with instruments focused on providing support to concrete research and innovation projects. IEA's Technology Collaboration Programmes, for example, often include sharing data, capacity building, joint R&D projects and even joint research infrastructures.

Table 4.4. Mechanisms and policy instruments for international STI collaborations for the SDGs

Mechanisms and instruments	Pillar 1: Building up national STI capabilities to address the SDGs	Pillar 2: Boosting international STI flows for the SDGs	Pillar 3: Brokering international STI collaborations for the SDGs
Strategic framework and governance	- Bilateral or multilateral diplomatic relations focused on STI issues (e.g. science diplomacy)	- Multilateral diplomatic relations focused on STI issues (e.g. science diplomacy) - Joint STI visions, strategies and action plans (e.g. STI strategies with shared targets or commitments)	- Global strategies to implement priority actions for the SDGs (e.g. transformative STI agendas or global missions) - Institutionalised new global STI partnerships addressing global challenges and the GPGs
STI capacity building	- Capacity building and institution building focused on aligning domestic STI governance, policy instruments and regulatory framework for the SDGs, including - Improving policy capabilities to (re)design STI framework conditions, notably regulatory frameworks - Building capabilities of researchers, research organisations, companies, civil societies and local communities to engage in STI for SDGs - Capacity building focused on building connections within national innovation systems critical for developing knowledge and innovation for the SDGs	- Supporting international movements of researchers and knowledge workers with a focus on developing knowledge and skills to address the SDGs - Sharing relevant national and international resources for STI capacity building - Jointly developed and delivered training programmes for governments and other stakeholders	- Developing new mandates and capacities to build and facilitate global STI coalitions and public-private partnerships for the SDGs, notably GPGs - Building new international institutional capabilities for mission-led transformative partnerships (including establishing global R&D and innovation centres) - Building global foresight and policy intelligence capacity
STI platforms and infrastructures	- Building country-level capabilities (see STI capacity building above), platforms and infrastructure ensuring access to international scientific data, education materials, technology information and good practices.	- Data sharing collaborations and platforms (e.g. open science platforms, collaboratively maintained databases, data philanthropy) - Platforms sharing good practices on design and implementation of policy instruments and regulations to enable the SDGs (e.g. designing regulatory frameworks for digital economy) - Regionally shared R&D and demonstration infrastructures - Regional business advisory and innovation support platforms (e.g. connecting technology hubs and innovation agencies)	- Sustaining and building new international large-scale research infrastructures such as CERN) - Developing new global STI platforms dedicated to gathering and sharing data and information on the GPGs - Agreeing on new globally-shared principles and standards on sharing information and data to monitoring aligned with the SDGs
Direct financial support to STI	- Focusing STI in ODA on the SDGs - Focusing funding from international donors on the SDGs - Initiatives focused on leveraging private finance for the SDGs, including blended finance	- STI programmes funding collaborative R&D engaging developing countries (including scientific, R&D and demonstration projects) - Funds supporting collaborative R&D and innovation projects for the SDGs (bilateral and mini-lateral)	- Joint economic instruments, including international STI programmes and funds focused on societal challenges (e.g. Horizon 2020 and Horizon Europe in the EU) - Removal of subsidies for unsustainable activities
Indirect financial support to STI	- *See STI capacity building*: Support in designing and implementing country-level indirect financial support measures to reward STI for the SDGs (e.g. fiscal policy)	- Exchanges of information and voluntary coordination of fiscal policies	- Alignment of fiscal policies to favour STI focused on the SDGs (e.g. carbon tax, removal of tax reliefs for unsustainable practices)
Regulatory framework	- *See STI capacity building*: Support in designing and implementing regulations and support to ensure country's compliance with international treaties and legal frameworks	- Treaties and legal frameworks establishing shared rules and standards which call for coordinated action (e.g. Nationally Determined Contributions under the Paris Agreement)	- New international treaties and legal frameworks establishing binding commitments, rules and standards to enable transition towards the SDGs (e.g. trade agreements, environmental regulations with binding targets).

Source: Authors

Collaborations under the third pillar may require unprecedented international policy alignment and coherence. To capture different levels of national-level policy alignment, OECD (2003) differentiated between policy coherence, policy coordination and policy consistency. Policy consistency means ensuring that individual policies are not contradictory. Policy co-ordination means getting the various institutional and managerial systems to work together. Policy coherence goes beyond coordination and consistency and ensures "the systematic promotion of mutually reinforcing action, by the concerned government and non-government players, in order to create and maintain synergies towards achieving the defined objective" (OECD, 2003). Addressing the SDGs requires to consider policy consistency, coordination and integration on the global level.

Striving for policy coherence is particularly important for policy interventions, aiming at enabling transformative system innovation, as it "aims to achieve much more than coherence or policy alignment since it involves actors outside government, notably firms and civil society, and takes a longer-term view" (OECD, 2015).

4.2.4. Policy learning, monitoring and evaluation

Ensuring that international STI collaborations, addressing the SDGs, are monitored and evaluated is crucial for drawing lessons from the past and on-going initiatives in order to improve the design of established and future collaborations, addressing global societal challenges. International STI collaborations should include arrangements for adjusting their design and activities in light of lessons learned from implementation and the changing external context.

When establishing M&E systems for international STI collaborations for the SDGs, partners need to consider a number of challenges:

- First of all, there are significant differences in M&E cultures and practices between countries, international organisations and private donors (OECD, 2012). These differences make it challenging to agree on an acceptable common approach and raise the risk of capture of the M&E process by one or a small group of partners.
- Second, challenge-oriented STI collaborations require specific conceptual and methodological approaches to M&E which require a well-developed evaluation and policy learning capacity on the level of individual countries and the coordinating entity.
- Third, M&E systems need to ensure that stakeholders and intended beneficiaries in different regions and localities take active part in the evaluation process. Key stakeholders should be actively engaged in discussing and assessing progress and suggesting changes to the overall design and implementation of concrete initiatives and projects. It is advisable, however, that evaluations are conducted externally by independent experts to avoid conflict of interest.
- Fourth, there is a need to ensure a balance between accountability and efficiency, as well as between input accountability (priority setting) and output accountability (efficiency) (OECD, 2012).
- Last but not least, it is key to ensure sufficient funding for M&E systems at the outset of the initiative.

Discussions on M&E should be a core part of the design and implementation of international STI collaboration for the SDGs. Employing tested good practices in programme design, such as co-designing intervention logic for collaborative programmes in order to visualize impact pathways expected from the intervention, is highly advisable for any form of international STI collaboration. International STI collaborations can benefit from good practices in building evaluation culture and institutionalizing M&E as a routine practice in STI collaborations and international organisations. International organisations invest heavily in evaluation and evaluation capacity (e.g. UN Evaluation Group or WB's Independent

Evaluation Group). CGIAR considers building M&E capacity in developing countries a core part of collaborations, which in the longer term allows for their fuller participation in these initiatives. It has a well-established practice in applying theory of change and impact pathways in designing their research programmes. They also commission comprehensive external evaluations, bringing a critical reflection on their activities.

Whilst many established practices in programme evaluations are relevant for assessing and designing international STI for the SDGs collaborations, there is a need for a dedicated reflection on how to improve and innovate current methodological frameworks (e.g. evaluation criteria, success criteria), evaluation processes (e.g. stakeholder engagement), indicators and data collection as well as analytical methods to better understand contribution of STI investments towards the SDGs. Specific effort is needed to ensure that M&E system allows to identify and assess impact, effectiveness and efficiency of STI activities and investments (e.g. summative evaluation) as well as to draw constructive lessons and improve ongoing collaborations (e.g. on-going formative evaluation).

Annex V presents an at-a-glance summary of issues relevant for international STI collaborations in the areas of governance and institutional setting, STI instruments and collaboration mechanisms and learning, monitoring and evaluation.

4.3. Using STI for SDGs roadmaps to engage in international STI collaborations

Many existing international STI collaborations can directly support the process of developing and implementing STI for the SDGs roadmaps. On the other hand, the roadmapping process itself can include internationalization of national STI system and building international linkages and collaborations as one of its integral dimensions.

The roadmapping process can benefit from:

- Existing international data sources and studies
- Internationally tested methodologies, methods and toolboxes
- Direct involvement of international scholars and experts
- Active engagement of international stakeholders in the process of formulation of the roadmap.

Table 4.5 outlines concrete suggestions on how international collaborations can be used at each step of STI for SDGs roadmapping process. It gives examples of existing activities, services and products already available from the members of IATT.

Table 4.5. International STI collaborations in developing and implementing STI the SDGs roadmaps

	International STI collaborations	**Examples of existing activities, services and products delivered IATT members**
1. Define objectives and scope	- Consider engaging independent international experts and scholars as advisers at the early stage of priority setting (e.g. to consult them on the scope of priorities) - Consider engaging key international stakeholders and existing international multi-stakeholder partnerships in consultations on key priorities and objectives (e.g. major international private and public investors, international NGOs, neighbouring countries etc.).	- EC JRC developed an open platform, overviewing strategic priorities of EU regions.
2. Assess current situation	- Use existing international databases and studies on the role of STI for the SDGs to inform the baseline analysis - Use available guidebooks and toolboxes introducing internationally tested methodologies and tools relevant for conducting baseline analysis - Engage international scholars and experts to make the baseline analysis more robust (e.g. via expert contributions or peer reviews) and/or to conduct dedicated capacity building on data sources, methodologies and methods to undertake baseline analysis. - Engage key international stakeholders and existing international multi-stakeholder partnerships in the process of preparation of the baseline analysis (e.g. evidence and case studies from major international private and public investors and international NGOs)	- STI policy reviews are conducted by UNCTAD, UNESCO, UNECE, WB, OECD and EC - UNESCO's Global Open Access Portal - IIASA and ISC conduct global studies on SDGs and their interdependence - International expert workshops and training can be supported by all IATT members
3. Develop vision, goals, and targets	- Use available international guidebooks and toolboxes introducing descriptions and examples of strategic foresight and planning methodologies and tools. - Engage key international stakeholders in the visioning process	- EC JRC, OECD and UNESCO conduct various foresight exercises and trainings, and have numerous guidebooks and toolboxes available
4. Asses alternative pathways	- Use available international guidebooks and toolboxes introducing descriptions and examples of strategic foresight and impact assessment tools. - Consider engaging independent international scholars and experts to support design and facilitation of vision building and scenario development processes and/or to conduct dedicated capacity building on these methodologies. - Engage key international stakeholders and existing international multi-stakeholder partnerships in deliberation of STI pathways, notably to consider how they relate to international developments and trends and to understand their potential future roles	- EC JRC and UNESCO conduct foresight exercises and trainings, and have numerous guidebooks and toolboxes available - IEA has dedicated competences in energy modelling, involving developing energy technology pathways.
5. Develop roadmaps for implementation	- Consider engage international experts to facilitate the process of designing intervention logic underpinning the roadmap. - Engage key international stakeholders in the process of preparation of the action plan if they are envisaged to be funders and/or have a role in implementation of specific action lines.	- Strong programme design competences across IATT (e.g. WB, EC, UNDP, UNIDO) - EC JRC provides support and conducts training in Smart Specialisation involving a strong component on developing roadmaps and action plans - WB provides support through its Advisory Services and Analytics to help develop roadmaps, action plans and relevant policies as well as knowledge-sharing workshops and trainings - IEA has dedicated competences in energy technology roadmapping.
6. Monitor evaluate and update plan	- Use available international guidebooks and toolboxes introducing descriptions and examples of evaluation methodologies and tools suitable for evaluating strategic roadmapping exercises. - Consider engaging independent international evaluation experts to support design of M&E system for the roadmap and/or to conduct dedicated capacity building on evaluation for the SDGs - Consider commissioning independent international evaluation experts to conduct external evaluation of the roadmap implementation - Engage key international stakeholders in collecting relevant data and interpreting M&E results	- Strong M&E competences across IATT (UN, WB, EC) - Numerous M&E trainings are available

Source: Authors

5. Overall findings and conclusions

STI is key for delivering on the ambition of Agenda 2030 and for accomplishing the SDGs. The effective use of STI to address the SDGs requires unprecedented efforts and investments from many countries, international organisations and many other stakeholders working together towards shared goals.

The rationale for international STI collaboration to address global challenges is stronger than ever. The world faces unprecedented social and environmental challenges, but at the same time it witnesses one of the fastest scientific and technological change in the history of humankind. A better international collaboration can ensure that STI has a focus on solving major global challenges as well as that the scientific and technological advances are shared broadly and fairly across countries, ensuring that no country or community is left behind.

The current challenges for international STI collaborations for the SDGs

The present system of international STI collaboration is not well equipped to cope with the grand challenges and address the SDGs. The international STI collaboration mechanisms in place favour scientific collaboration focused on basic research and to a lesser extent, applied research. The direction of international collaboration in research, with the exception of the EU, remains primarily driven by "bottom up" priorities of individual researchers and research organisations, even if there are increasingly international STI collaborations on climate change, global health, renewable energy or sustainable agriculture initiated via "top down" processes. The predominant objective remains, however, to strengthen national research systems by engaging in international collaborations, rather than to build an international innovation system, which could enable wider adoption and diffusion of technology and innovation, especially in developing countries.

The level of STI investments through ODA remains generally low. While international research collaboration through ODA activities has increased in some countries, such as the Germany, Japan, UK, and the United States, total financing for research and technology within ODA is limited. Concessional finance to STI is estimated to range from USD 10 billion to over 20 billion per year, representing six to 10% of total concessional finance by DAC members, multilateral organisations and other countries. This may be partly explained by the historical disconnect between policy communities responsible for promoting development through ODA and the mainstream STI policies both on the national and international level.

On the other hand, there are some positive developments. A growing number of existing and new international collaborations consider STI key for achieving the SDGs. Among established international organisations, the CGIAR and IEA actively engage in and build international partnerships for the SDGs. Mission Innovation or Global AMR R&D Center are among new international STI partnerships with explicit missions to enable new international STI collaborations addressing the SDGs. Importantly, some new international collaborations and partnerships involve private philanthropic funding in STI in developing countries which, although relatively low, has been showing a growing trend. This is, for example, the case of the Coalition for Epidemic Preparedness Innovations (CEPI), a partnership between public, private, philanthropic, and civil organisations to stimulate, finance and co-ordinate vaccine development against epidemic diseases.

Three pillars of the international STI collaborations addressing the SDGs

The innovation challenge facing the international community today is to harness benefits of STI so to enable and accelerate the global transition towards sustainable development. International STI collaboration is necessary for strengthening capabilities of developing countries to benefit from STI as well as for strengthening the international STI collaborations to address global societal challenges more effectively as a global community.

In order to capture various dimensions of international STI collaboration for the SDGs, this background paper proposed to consider three broad objectives – or three pillars - of international collaboration:

- Pillar 1. Building up national STI capabilities to address the SDGs: focus on strengthening national STI capabilities, mostly of developing countries, to address challenges underpinning the SDGs.
- Pillar 2. Boosting international knowledge and technology flows for the SDGs: focus on boosting international flows of relevant knowledge and technology across countries and on supporting cross-country STI collaborations, addressing the SDGs.
- Pillar 3: Brokering international STI collaborations for the SDGs: focus on brokering international collective STI actions with an ambition to tackle global challenges, notably the GPGs.

Strengthening national innovation systems and building sustainable sociotechnical systems in developing countries will be necessary to achieve the broader sustainable development goals set out in Agenda 2030, including urgent environmental challenges such as climate emergency. Any well-functioning NIS needs to be connected internationally to enable the flow and development of knowledge, skills and innovation (Ockwell & Byrne, 2016). This in turn is key to brokering strong international STI coalitions tackling global challenges.

Countries and international community need to engage in all three pillars of international collaboration to effectively mobilise STI for Global Goals. The pillars are mutually reinforcing and interdependent. For example, international collaboration for building national STI capabilities is key for developing a stronger basis for international partnerships. On the other hand, boosting international STI flows will directly help building national STI capacities. Meanwhile, actions conducted by global STI partnerships addressing specific challenges can help develop specific domestic capabilities in developing countries, which are "hot spots" of major global challenges (e.g. sustainable fisheries, sustainable forest management).

Whilst there are examples of major scientific collaborations mobilising scientists around the globe, such as notably the UN IPCC, there are, however, few examples of international collaborations with a dedicated focus on orchestrating and conducting collective actions to co-develop and deploy innovations at the scale adequate to achieve transformative impact.

There is a need for more international STI collaborations, which aim at brokering international STI collaborations for the SDGs. Transformative innovation policy and mission-oriented innovation policies could become policy frameworks allowing for a more collaborative mode of STI. They would, however, have to integrate a parallel focus on all three pillars, notably to ensure that developing countries have resources and opportunities to build their STI capacities while contributing to resolving global challenges.

Considerations for future international STI collaboration for the SDGs

The success of future international STI collaborations for the SDGs will require a transition from competitive to a more collaborative mode of STI, in which shared goals and missions underpin individual and collective STI actions. Innovation for the SDGs needs to address problems that individual countries cannot solve by acting alone. Therefore, competition must be balanced with collaboration in order to share resources and develop and deploy transformative innovations. Innovation for grand challenges requires that policymakers adopt a broader view of the benefits of international STI cooperation that include not only economic gains but also creating present and future public value by contributing to systemic transitions at both national and global level.

There should be a collective reflection and arrangements for sharing and distribution of direct costs and public and private benefits that may be created. The increasingly globalised nature of innovation provides an additional rationale for international STI collaborations for the SDGs. The ability of countries to meet their own national challenges can be enabled and strengthened by international co-operation.

There is a need to align national STI policy agendas with the SDGs and develop new instruments and partnerships to connect national efforts with collaboration on global challenges in both developing and developed countries. Evidence suggests that the most effective collaborations are aligned with the domestic policy agenda of key partners.

In donor countries, there is room to improve policy coherence by streamlining challenge-oriented STI policies with ODA. In many developing countries, STI-related efforts can better be coordinated and synergised among ministries, international partners and key stakeholders. At global level, knowledge and experience sharing, dissemination and application of good practices, and designing new or improving existing mechanisms can better be informed and targeted through concerted analytical and facilitation efforts.

Achieving the SDGs calls for a concerted international effort, engaging various stakeholders from business, research and governments, operating at different levels of governance. Multi-stakeholder international STI collaborations are needed to challenge dominant business models, redesign entire functional systems, change urban and rural landscapes, and advance new governance and policy frameworks. Whereas traditional STI collaboration involved collaboration among scientific organisations or between governments (i.e. via bilateral and multi-lateral agreements), global challenges require engagement with a broader range of stakeholders, including companies, charities, foundations and civil society groups.

When reflecting on innovation for the SDGs, it is important to apply relevant scientific knowledge and technical solutions to problems in their specific local contexts rather than simply aiming at introducing most technologically advanced novelties. The specific challenge for developing countries is to build systemic capabilities to absorb and diffuse existing knowledge and technologies while nurturing their local knowledge and entrepreneurial eco-systems. International STI collaboration can make a considerable contribution to this process by supporting endogenous innovation potential in developing countries and, at the same time, by strengthening their capacity to access and exploit external finance, knowledge and innovation.

There is a significant gap in evidence on investments and impacts of international STI collaborations targeting the SDGs. Building up a more comprehensive and robust evidence base on international STI collaborations is a prerequisite to improving the design and implementation of ongoing and future international STI initiatives focused on resolving global challenges. There is an urgent need to improve and innovate methodological frameworks, processes, and metrics used to evaluate the contribution of STI towards the SDGs. These metrics need to go beyond research excellence and focus on wider socio-economic and environmental impacts.

Furthermore, there is a need to strengthen and nurture international collaborations focused on sharing data and discussing evidence on impacts of STI on the SDGs in developing countries. As there will always be gaps in data, such collaborations, bringing together interdisciplinary communities of experts and stakeholders, are essential to ensure that lessons from good practices and failures are discussed and shared internationally. With their prominent focus on M&E and policy learning, STI for SDGs roadmaps could play a central role in bridging the knowledge gap and building up international evidence base on STI for SDGs.

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Annex I. Typologies for mapping international STI co-operation initiatives

	Description	Possible typologies to classify international STI collaborations	Further analytical reflection
Main goals and thematic focus	What are key goals of international STI collaborations?	1) SDGs addressed by the collaboration (goals and possible target level) 2) Underpinning STI paradigm/innovation policy frame (Gassler et al., 2008; Mazzucato, 2017; Schot & Steinmueller, 2018): R&D; industrial policy (technological upgrading); innovation system; transformative or mission-oriented innovation	To what extent are objectives of international STI collaborations aligned with the SDGs? To what extend are they aligned with the national development priorities?
STI areas, processes and outcomes	Which areas, processes and outcomes of science, technology and innovation are addressed by international STI collaborations?	1) Focus on science, technology and innovation (multiple choice; possibly indication of the relative focus on science versus innovation 3) Focus on specific segments of innovation chain (Wilson et al., 2012): - Research - Development - Demonstration - Market formation (niche market) - Diffusion (mature) - Phase-out 4) Focus on scientific disciplines (multiple choice; balance between natural, concrete and social sciences and between basic and applied science) 5) Technology areas and/or economic sectors (multiple choice) 6) Technology maturity (such as Technology Readiness Levels - TRL) 7) Types of innovation supported - Process; Product or service; Organisational; Marketing; Social innovation; Grass-roots innovation; System innovation 8) Level of novelty of innovation to be supported - New to firm/organisation; New to country; New to (macro)region; New to world	How is STI applied in international STI collaborations to address societal challenges? What is the relative role of scientific, technological and innovation collaboration? Are there collaborations which address all three areas?
International collaboration mechanisms	What are mechanisms of collaboration promoted by international STI collaborations?	1) Mechanisms of STI collaboration - Information access and sharing (e.g. databases) - Capacity building and education (focused on policy-making capacity or directly on science, technology and/or innovation capability) - Joint projects - Joint strategies - Joint instruments (e.g. innovation funds, R&D programmes) - Scientific diplomacy - International research infrastructures (e.g. CERN) -Treaties and legal frameworks (e.g. IPR, trade, environmental regulations)	How to adapt collaboration mechanisms to best respond to the challenge addressed by the initiative while recognising existing differences in institutional capacity? What could be novel mechanisms and instruments to improve effectiveness and efficiency of international STI collaboration?

	Description	Possible typologies to classify international STI collaborations	Further analytical reflection
Governance and coordination	Who are key actors involved in the international STI collaborations? How are international STI collaborations coordinated? What are their institutional settings?	1) Scope of collaboration - bilateral, minilateral, multilateral 2) Institutional setting - Informal network with no formal mandate or institutional setting - Project-based international networks - Collaboration institutionalised as a part of existing IO, NGO or company - Collaboration institutionalised as a new IO, NGO or company 3) Actors (type; multiple choice) - International organisations; Governments; Universities; Research institutes; Researchers; Large companies; SMEs; Charities; NGOs 4) Geographical coverage 5) Level of policy coordination (Metcalfe, 1994) - Independent decision-making by ministries; Communication between ministries (info exchange); Consultation with other ministries (feedback); Avoiding divergences among ministries; Search for agreement among ministries; Arbitration of policy differences; Setting limits on ministerial action; Establishing central priorities; (Shared) government strategy	What is the desired level of policy coordination to address the SDGs? How to address the need to enhance policy coherence taking into account politically viable levels of policy integration, and respecting the policy space of developing countries? What are forms of STI governance which can be most effective in addressing urgent issues? How to design evaluation and monitoring systems for international STI collaborations to ensure both their accountability and effectiveness?
Funding model	What are funding models and funding channels of international STI collaborations?	1) Funding model - Mainly core funding; Mainly project-based; Mixed models 2) Sources of funding 3) Multiannual planning	To what extent are existing funding models allowing to manage diverse interests of international and national funders, and minimise the risk of capture? How to ensure long-term funding for international STI collaborations?

Source: Authors

Annex II. Methodology applied to identifying STI-related ODA and other external finance in the CRS database

Identifying STI-related ODA and other external finance in the CRS can be performed in two ways: assessing ODA expenditures from provider countries or examining the inflows of development finance into developing countries. The difference between these two approaches is whether to examine STI-related development finance from a donor or recipient angle. The donor angle will include core funding to multilateral agencies (also referred to as "multilateral ODA"), while the recipient angle will include the outflows from multilateral agencies. The approach taken in this paper is to focus on the total inflows of concessional financing into developing countries. Taking the developing country angle makes more sense to assess the amount of resources available to countries towards the attainment of the SDGs.

The current limitations of the CRS make identifying activities supporting innovation and technology beyond ICTs complex. Classificatory variables exist in the CRS to identify development activities that support research programmes or scientific networks and partnership for improved knowledge-transfer between developed and developing countries. It is also possible using the existing structure of the CRS to identity projects and other activities aimed to support countries' efforts to expand ICT infrastructure and strengthen their digital economies. However, the CRS currently lacks any classificatory variables, which can support the identification of technology-oriented activities, e.g. technology transfers, or activities supporting innovation and innovation policy. The methodology used in this paper aims to capture support to innovation and technology beyond ICTs by exploring the description fields in the CRS.

For the purpose of this analysis, a three-tier approach was developed to identify STI-related activities. The reason for the three-tier approach was to use the available classificatory variables to the maximum extent but complement these with additional activities identified using text mining techniques. The three-tiered process was a response to the lack of convenient structure in the CRS for identification of activities supporting STI. By using complementary information across variables, a broader view on STI-related development finance can be presented.

The first stage includes identifying core activities, which are those activities that can be easily identified to supporting research and ICT development through the CRS sector codes (see Annex III for more information on these sector codes). These activities are often core support to universities or other research institutions or financing for other larger research programmes, e.g. the such as Canada's Development Innovation Fund for Global Health Research and the Norwegian Programme for Global Health and Vaccination Research, which support research towards improving the health for people living in low-and lower-middle income countries. The activities identified through the sector codes also includes support for telecommunication and other ICT infrastructure developments in countries and regions as well as other initiatives to strengthen digital skills or bridging the digital divide.

The second stage identifies STI activities implemented by entities that are on the OECD DAC list of channels of delivery. There are currently 355 entities on the list. It includes NGOs, PPPs and networks, multilateral organisations, universities, college or other teaching institution, research institute or other think-thanks. The list also includes broad categories of public and private sector institutions. The entities identified in this paper has STI as their focus. The entities are either conducting research, supporting access and use of ICTs, or financing projects relating to technology transfer, e.g. projects supporting renewable energy. In total, 65 entities have been identified to support STI, of which 27 are classified as universities or other research institutes.

The list of identified entities includes support to organisations and initiatives focused on a specific theme. For example, the list includes the International AIDS Vaccine Initiative (IAVI), which aims to develop vaccines and other innovations for HIV prevention, and research for agricultural development and food security conducted as part of the CGIAR network. It also includes support to entities aimed to strengthen the ICT capacity in developing countries, such as the Development Gateway, which build digital technology tools and processes, the Global e-Schools and Communities Initiative, which support greater use of ICTs in education, and Commonwealth of Learning, whose mandate to promote open and distance learning using technology-based approaches. While there are other entities on the list, which also conduct research as part of their work programme, e.g. multilateral organisations, research is often not their main activity. Contributions to or through these entities are therefore not included in this analysis as it cannot be determined that all funding supports STI.

For the purpose of this paper, all official development finance (both concessional and non-concessional) channelled through universities or other research institutions are considered as support to STI. Most of these funding refer to research activities conducted by universities; however, in many cases these activities also include elements of capacity building. These capacity building trainings and workshops are often aimed at faculty, students, and other researchers and public servants in developing countries. For the purpose of this analysis, it is assumed that these trainings contribute towards enhancing countries' STI capacity. However, it is likely that the inclusion of all development finance channelled through universities over-estimates the amount of development finance supporting STI.

The last third stage identifies development activities using text-mining methods applied to the providers' descriptions of activities in the CRS. Providers are required to include text descriptions of the activities when reporting to the CRS; however, in practice this information has been difficult to use for analytical purposes because of the differences in quality of the descriptions. While some providers include nearly half a page of information for one single activity, other providers may restrict the amount of information to a few words. Nearly all descriptions are in English; however, other languages are also used, which further adds challenges to synthesising the information. Considering that the CRS contains approximately 250 000 activities per year, it has previously been challenging to process the amount of information captured in these descriptions.

The frequency of words used in the description of development activities were analysed to identify the most appropriate keywords. Natural Language Processing (NLP) algorithms were used to identify the most prominent keywords in the description of activities supporting research and ICT development identified using the sector codes in the first stage. Approximately 22,000 activities supporting research and 12,000 activities supporting ICT development for the years 2013-2016 were assessed. Common 'filler words' such as "the", "is" and "are" were excluded from the analysis.

The most prominent keywords were used to identify additional development activities with an STI component, which had not already been identified in the first of second stages. Several checks were performed to assess the results, including manual checks of the development activities identified. If a specific keyword did not seem to capture activities with an STI element, e.g. if the keyword "research" referred to "market research", the keyword was removed or modified.

A robustness test was made to assess the relative importance of the specific keywords used to identify research and ICT activities. The prevalence of the most frequent words identified in the "core" STI activities identified through the sector codes was compared against the prevalence for the same words across the description of all other activities in the CRS. The results indicated that the keywords used for the analysis were strongly linked to activities supporting research or ICT development. For example, keywords such as "ICT" and "digital" were more than 50 times more frequent in the description of core ICT activities than in other activities. Other words such as "Internet", "broadband" and "cyberspace" were more than 100 times as frequent. Similarly, words such as "scientific" and "research" were more than 10 times more frequent in "core" research activities than in other development activities. This analysis indicates that these keywords are appropriate to identify additional development activities supporting STI, which had not already have been identified in the first or second stages.

The combination of these three methods capture a broader range of STI activities than simply relying on CRS sector codes. This approach also captures development finance providers' various preferences to support STI. For example, some providers may prefer to support research for which there is no sector code, e.g. infectious diseases. Other providers may prefer core funding to certain institutions, which have core STI mandates but may or may not be present on the DAC list of channels of delivery.

The classification of activities by STI is based on the available variables and criteria to identify the activities. Development finance towards science includes spending on activities classified as research through CRS sector codes (stage 1), core funding or earmarked funding through research entities (stage 2), and additional finance of activities with a research component that have been identified using text mining (stage 3). The identification of development finance towards ICTs and other technologies follow a similar approach; however, the accuracy in identifying activities with a technological component may be less than for research, considering the limited number of technology-specific sector codes (stage 1) and the larger heterogeneity in technology-oriented keywords. The approach used in this paper to identify technology-oriented activities is biased towards ICT-oriented activities.

Improved classification in the CRS can strengthen the methodology to assess contributions from development providers towards STI-related projects. Further developments in the CRS, e.g. new sector codes, policy-markers, channels of delivery and reporting on the SDG target, may be necessary to improve the identification of STI-related development finance, while the development of Total Official Support for Sustainable Development (TOSSD)[13] could provide a better picture of the development finance, including mobilised private finance and the finance devoted to development enablers and global challenges. In addition, future work may consider other sector codes as support to STI, e.g. sector codes relating to renewable energy or energy efficiency.

Further analyses using machine-learning techniques can improve the robustness of the text mining analysis. The text mining analysis used to identify additional activities with STI-related components in stage three are based on development providers´ current reporting of their activities to the CRS. The records used for the analysis are based on current CRS classifications and descriptions of development activities, and not official STI documents. This makes the identified keywords vulnerable to the quality of development providers´ reporting, which can vary on a yearly basis and across providers, and to the specific development activities conducted in those years. For example, if a provider conducts a large research study of ecosystems in the rainforest and includes detailed descriptions of these activities in its yearly reporting, then the machine learning algorithms will have greater likelihood to pick up keywords not only relating to the research conducted but also to specific terms relating to the flora and fauna of the rainforest. As such, the NLP algorithms rely on the source of information rather than the most appropriate terms and concepts. While several manual checks were performed to examine the activities identified by the keywords, the algorithms used in this paper could be improved by examining official STI documents, identifying core keywords distinctively from the CRS.

[13] TOSSD is an international statistical framework for monitoring official resources, and private finance mobilised by official interventions, in support of sustainable development. http://www.oecd.org/dac/tossd/

Annex III. Methodology applied in World Bank's analysis of STI-ODA intersection

Using OECD CRS database as the primary data source, the World Bank analysis performed a three-steps approach to calculate the top donors' share of development finance towards STI disbursed in 2017. Additional steps like sub-categorizations were taken to better capture the detailed landscape of STI-ODA intersections. The following is explanations of data sources of this analysis, the STI activities identification process, and the STI definitions in greater detail.

Data Sources

The OECD CRS is the major data source this analysis used.[14] The CRS contains data on ODA flowed annually from OECD DAC members to developing countries or multilateral organizations, and documents both commitment and net disbursement amount. This analysis only extracted CRS 2017 ODA disbursement data of selected top donor countries – US, UK, Germany, France, and Japan.[15] In other words, this analysis only focused on bilateral aid projects of the five top donor countries, disbursed in calendar year 2017, while bilateral through multilateral and multilateral support are not within the scope of this study. The aggregated data includes the project or program title and description; the ministry or agency funding the assistance; the country and region receiving the aid; the delivery channel and financial instrument that the transactions are intended to use, and the aid type and sector that the projects are designed to support.

Since the CRS aid activities data are submitted by different entities from countries, gaps between each country's data exist and thus, additional data sources are required to fill the gaps. Providers are required to include text descriptions of the activities when reporting to the CRS, but the quality of the descriptions vary. As a result, additional data sources were used for UK, Japan, Germany and France in this WB analysis. UK online aid project database – Development Tracker is the secondary data source used to validate UK aid projects or activities' information. Similarly, GIZ website[16] and AFD website[17] were used to match, compare and validate German and French projects. Japan International Cooperation Agency's online ODA data platform, (government-funded projects) review sheets, and Japan's lists of ODA budget and STI budget are the additional data sources used to draw the full picture of Japan's international activities in STI and ODA intersection.[18] Additionally, WB sources[19] were used supplementary.

Methodology for identification of STI-related projects and activities

The variables from the CRS and additional data sources cannot easily and clearly identify aid projects with an STI focus. As a result, three major steps were taken to identify STI-related projects in this analysis, as summarized below.

The first step was to link the STI funding sources with existing projects in the dataset and label them as STI-related activities. Each country has its flagship STI initiatives, and projects funded under those initiatives contain STI elements. For example, UK Newton Fund aims to strengthen partner country science and innovation capacity through collaborative research and capacity building. So, all the

[14] Due to data quality limitation, France is not included in this analysis.

[15] Top donor countries in absolute term from high to low are US, UK, Germany, Japan, and France.

[16] GIZ website includes project information for not only GIZ but also BMZ: https://www.giz.de/en/html/worldwide.html

[17] https://www.afd.fr/en

[18] For STI budget and ODA budget, both initial budget and supplementary budget were included in the data. Sub-national (e.g. prefectural, municipal) budget data were not available and hence not included.

[19] For example, https://data.worldbank.org/topic/science-and-technology

fellowship and collaboration activities funded by Newton Fund in the dataset were identified as STI-related activities at this stage.

The second step included the identification of STI activities using keyword search method. A list of keywords related to science, technology or innovation was created to filter out STI elements. If a project title or a project description includes any one of the listed keywords such as “research”, “digital”, or “entrepreneurship”, then the project would be labelled as STI. The list also includes incomplete words for the purpose of expanding the collection range. For instance, the keyword referring to innovation or innovative activities is “innova”, and the keyword referring to entrepreneurship development or entrepreneur network support is “entrepre”. The translation of some of these keywords into other languages like Japanese and French were used while the keywords filter database for the analysis of Japan and France data had slight modifications.

After the initial screen and check, a list of exclusion keywords was also created to filter out the misleading content. For example, in Japanese “技術” means technology, as well as technical. However, project descriptions or titles include technical, especially “技術協力” (technical assistance), are not necessarily STI activities. So, the word “技術” needs to be marked out and if any projects only contain “技術協力” (technical assistance), they would not be counted as STI projects.

In addition, as Japan data also includes STI budget items[20], a similar attempt was made to extract ODA-like STI projects using keywords. Keywords in this case are hence designed to be responsive to ODA-like research activities such as “途上国” (developing country) and “新興国” (emerging country/economy).

The third step involved the manual adjustments of keyword search results. In this analysis, the next step was to manually check and adjust the results of keyword search for all the selected countries. At this stage, projects that hit any keywords previously but considered non-STI centric were omitted from the STI list. For example, "remote" could be a part of STI-related words, such as remote-control technology but also could be non-STI related, such as remote suburban areas. Because “remote” cannot be simply excluded in the list, manual screening was necessary.

Similarly, the projects that did not hit any keywords before but considered STI were added to the analysis. Further desk research was performed for projects which cannot be easily judged by descriptions or titles.

To be noted, UK’s aid activities data is at one more granular level (activity level) than peer countries’ (project level). So, one additional manual inclusion step was taken to aggregate UK activity level data and make them comparable to others. UK activities under the same projects share the same project description but with different project titles. All the activity data with duplicated project descriptions have been checked manually. For those projects with a very large STI portion, all the activities under those projects would be marked as STI even if some activities titles didn’t hit keywords.

STI Definitions

The STI definitions used in the study are based on the UN Guidebook on Development of STI for SDGs Roadmaps. According to the Guidebook, Science, Technology and Innovation (STI) are three different

[20] Since Japan’s STI-related ODA-like projects (such as research conducted in Japan to address global/local issues in developing countries, which peer countries would count as a part of their ODA activities) were often missing from Japan’s ODA budget list due to a different ODA reporting system from peer countries’, Japan’s project list under STI budget was also consulted as an additional data source to keep consistency among all five countries.

domains encompassing the research studies, the development of new technologies, and other forms of innovation to produce or use goods and services. They affiliate with distinct sets of actors but with strong relationship among them.

- **Science is fundamentally the pursuit of knowledge** through systematic studies of the structure and behaviour of the physical and natural world and societies. Scientists or researchers, across public and private institutes, are the key actors often organized and represented through academies of sciences. Governments typically have a responsible ministry for science policies and funding agencies administering research programs.
- **Technology is the practical application of knowledge for a given end**. Publicly funded scientists conducting applied research, as well as private sector engineers and product/service developers, are the key actors in developing and applying new technologies. Yet, broader actors in industries and governments' line ministries disseminate, adopt or adapt existing technologies, such as for agriculture, health, infrastructure and environmental purposes.
- **Innovation is a new way of producing or using goods and services**, based on new technology, or through new business models or forms of economic or social organization. While also applicable to public administration and service delivery, innovation is largely private undertaking by industries and entrepreneurs as well as civil society organizations, including through adoption and adaptation of conventional technologies.

As explained in Annex II, OECD had also conducted a similar analysis on donor countries' and large multilateral organizations' official development finance supporting STI development based on different STI definitions and methodologies. Their approaches mainly focus on identifying research activities and ICT related projects and lack identifications of some technology-oriented activities and support to innovation. The OECD methodology also overestimates the disbursements by counting all the core funding to the research and ICT-related entities as STI spending.

STI sub-categorizations

In order to better understand the concept and conduct comparative analysis for peer countries, the EB team for this analysis defined nine sub-categories for science, technology and innovations activities in development assistance projects.

Science

1. **Science and research capacity**: Projects help to build developing countries' R&D capacity through institutional support including developing school infrastructure construction, providing or improving education program including STEM education at all levels, and building network, as well as through individual support to researchers in recipient countries via fellowship/scholarship program or training for not only scientists but also policy-researchers and policy-makers.
2. **Science and research activity - RECIPIENTS**: Projects help recipient countries to tackle development challenges and analyse policies/strategies through R&D activities. Those projects are conducted by recipient countries' universities, research institutions or individual researchers.
3. **Science and research Activity - PROVIDERS**: Projects provide funding or training to researchers or research institutions in developed countries to perform research activities to tackle developing countries' challenges; Those would also include scholarships to invite students from developing countries to study and train in developed countries.

Technology

1. **Technology-intensive infrastructure**: Projects involve physical constructions or major upgrades of telecommunications, transportation control systems, renewable energy and energy efficiency related grids or plants, and other utilities (such as medical/research complex and radars), of which require the use of technologies.
2. **Industrial technology-transfer and capacity-building**: Projects enable recipient countries' industries to acquire knowledge and skills through Technical Vocational Education and Training, and/or provision by providers of hardware equipment, systems mechanisms and models for recipients to utilize and benefit from "conventional" technologies in various industries, including transportation, manufacturing, energy, environment, agriculture, health, and disaster management. Those projects of policy support for better disseminations of technologies in one particular sector, such as clean energy technologies fall under this sub-category as well.
3. **Digitization/ICT**: Projects involve heavy use of digital and other ICT applications /solutions to digitize government services, such as business registration, customs processes, land administration and public health or agricultural forestry decision-making. This group also includes initiatives on open data or big data (i.e. by accessing to GIS, satellite data), cyber security, citizen identification and social accountability. Those projects in capacity/human resource development in ICT are also included in this sub-category.

Innovation

1. **Support for innovation ecosystem**: Projects are provided for the purpose of productivity growth and job creation for both government and industries through strengthening academia-industry-government collaborations, establishing innovation/entrepreneurship promotion agencies, and regulating related enabling environment including with IPR, framework, standards and norms, possibly for a specific sector (i.e. green energy).
2. **Support for entrepreneurs, SMEs and microenterprises to start or scale up innovation**: Projects can be done through star-up incubation (through venture capital or equity investment), early stage financing project/challenge programs (for demonstration, testing and scaling-up), networking, learning centres, often to achieve social and inclusive innovation for the poor and the vulnerable.
3. **Enhancing organizational / firm innovation capability**: Projects helps local producers, SMEs, larger firms, or specific industries and sectors improve efficiency and/or productivity through process innovation. The guaranteed safety of products for firms are included in this sub-category.

The STI data were classified into these nine subcategories through the keywords search and manual adjustment. To sort out each individual project into one of the subcategories listed above, another two-steps approach similar to the STI filtering process was taken—the keywords search for project titles and descriptions, followed by the manual screen. For example, the analysis used keywords 'research capacity' and 'STEM' to flag S1 projects, 'solar plant' to mark T1 projects, and 'entrepreneurship' to label I2 projects. To fine-tune the subcategorization results, one more step was taken to check the exercise results manually and adjust the marks.

Annex IV. Case studies of international STI collaborations relevant for the SDGs

Case 1. Technology Collaboration Programmes by International Energy Agency (IEA)

The Technology Collaboration Programmes (TCPs) provide a flexible collaboration mechanism for IEA member and partner countries, including governments, industries, businesses, and regional or international organisations. TCPs aim to advance the research, development and commercialisation of energy technologies in line with the IEA Shared Goals of energy security, environmental protection and economic growth. The programme focuses on five broad technology areas: energy efficiency technologies (buildings, transport, industry and electricity), renewable energy and hydrogen, fossil fuels, fusion power, and cross-cutting issues. The outcomes of TCPs are directly relevant for SDG7 and SDG17, contribute to SDGs 9, 11, 12 and 13 and have indirect relevance for virtually all SDGs.

The IEA Governing Board (composed of energy ministers from IEA member countries) approved the establishment of TCPs in 1975 as the principal IEA tool for multilateral technology collaboration. Since then some 80 TCPs have been created, with 38 currently operating. These collaborations involve over 6,000 experts worldwide who represent nearly 300 public and private organisations from 55 countries, including emerging economies such as China, India and Brazil.

TCPs are collaborative programmes established by at least two IEA member countries that are governed by binding contractual agreements. Programmes or projects carried out under the TCPs may include: building or operating a pilot plant; engaging in a joint study (basic or applied research); collecting data and managing a database; energy modelling to produce technology scenarios; maintaining experts' networks; facilitating technology or knowledge transfer through training, or workshops; project funding; scientist exchanges; or dedicated communication efforts. TCP activities have produced a range of results including inventions, pilot plants, demonstration projects, databases and development of standards.

TCPs are functionally and legally autonomous from the organisational structure of the IEA. They are organised under the auspices of an Implementing Agreement, including key provisions regarding the purpose, management and implementation of the TCP. The activities of each TCP are overseen by an executive committee (ExCo) comprising representatives designated by each participant.

There are two categories of participants of TCPs: Contracting Parties and Sponsors. Contracting Party (CP) represents governments of OECD member or non-member countries, the European Union, or intergovernmental organisations. CPs may be national agencies or private corporations designated by a government to participate in a TCP. Sponsor Participants are not designated by a government to participate in the TCP. This may include public and private sector entities, as well as non-intergovernmental organisations. Non-governmental entities have been encouraged to participate in the TCPs as Sponsors since 2003. Since then, participation of non-governmental entities has gradually increased. For example, a significant number of multinational enterprises and industries participate as Sponsors in two TPCs, focusing on coal (CCC TCP and GHG TCP), and industry associations participate as Sponsors in several TCPs on renewables. Some TCPs entrust the management functions or particular activities of the TCP to an operating agent (OA).

The IEA does not provide direct financial support to TCPs through funding. The funding is provided by CPs and Sponsors. The IEA Secretariat provides guidance, advice and support by acting as conduit between TCPs and policymakers, and by promoting TCP outcomes. The IEA also provides legal advice in relation to processes, procedures and the legal structure of TCPs.

Sources and further information:

- TCPs webpage - https://www.iea.org/tcp/

- IEA (2019) Energy Technology Innovation Partnerships. June 2019. IEA Publications International Energy Agency.
- IEA (2016) Technology Collaboration Programmes. Highlights and Outcomes. May 2016. IEA Publications International Energy Agency.

Case 2. Mission Innovation

Mission Innovation (MI) is a global initiative launched on 30 November 2015 at COP21 in Paris to reinvigorate and accelerate global clean energy innovation with the overall objective to make clean energy widely affordable. MI groups 24 countries[21] and the European Commission.

The goal is "to accelerate the pace of clean energy innovation to achieve performance breakthroughs and cost reductions to provide widely affordable and reliable clean energy solutions that will revolutionize energy systems throughout the world over the next two decades and beyond." The collaboration is directly relevant for SDG 7 "Affordable and Clean Energy" and SDG 13 "Climate action".

The key actions of the MI's Action Plan include: Doubling investment in clean energy research, development and demonstration (RD&D) in each MI member country by 2021; Information sharing between members, involving sharing information on plans for clean energy RD&D and facilitate cooperation involving investors, business and industry; Innovation analysis and roadmapping; Joint Research and Capacity Building including facilitation of bilateral and multilateral research partnerships; and Business and Investor Engagement including working on encouraging investment in emerging technologies.

Increasing international collaboration, focused on sharing lessons learned, improving coherence and building synergies between MI countries, is one of the priority areas. MI encourages members to form bilateral and multilateral clean energy research, development and demonstration (RD&D) collaborations. In May 2019, for example, it launched an alliance with the Global Covenant of Mayors for Climate Change to identify shared innovation priorities and deliver innovative and integrated technologies at the city level.

To focus international collaboration on priority areas, MI put forward Innovation Challenges (ICs). ICs are "global calls to action aimed at accelerating RD&D in technology areas that could provide significant benefits in reducing greenhouse gas emissions, increasing energy security and creating new opportunities for clean economic growth". Work under the IC is guided by four objectives:

- Building an improved and shared understanding of what is needed to address the Challenge, and how to define measurable targets and track progress towards them;
- Identifying key gaps and opportunities not sufficiently addressed by current activities;
- Promoting opportunities for researchers, innovators and investors in order to build support and excitement around the Challenges and boost engagement; and
- Strengthening and expanding collaboration between key partners, including governments, researchers, innovators, and private sector stakeholders.

The ICs cover the entire spectrum of RD&D from early-stage research needs assessments to technology demonstration projects. Each IC consists of a global network of policymakers, scientists and innovators working towards a common objective and built around a coalition of interested MI members. Through

[21]Australia, Austria, Brazil, Canada, Chile, China, Denmark, Finland, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Morocco, Netherlands, Norway, Saudi Arabia, Sweden, United Arab Emirates, United Kingdom, United States. The European Commission is a member on behalf of the EU.

the ICs, MI members aim to encourage increased engagement from the global research community, industry, and investors, while also providing opportunities for new collaborations between MI members.

The current ICs include:

1. Smart Grids Innovation Challenge – to enable future grids that are powered by affordable, reliable, decentralised renewable electricity systems;
2. Off-Grid Access to Electricity Innovation Challenge – to develop systems that enable off-grid households and communities to access affordable and reliable renewable electricity;
3. Carbon Capture Innovation Challenge – to enable near-zero carbon dioxide (CO_2) emissions from power plants and carbon intensive industries;
4. Sustainable Biofuels Innovation Challenge – to develop ways to produce, at scale, widely affordable, advanced biofuels for transportation and industrial applications;
5. Converting Sunlight Innovation Challenge – to discover affordable ways to convert sunlight into storable solar fuels;
6. Clean Energy Materials Innovation Challenge – to accelerate the exploration, discovery, and use of new high-performance, low-cost clean energy materials; and
7. Affordable Heating and Cooling of Buildings Innovation Challenge – to make low-carbon heating and cooling affordable for everyone.
8. Renewable and clean hydrogen - To accelerate the development of a global hydrogen market by identifying and overcoming key technology barriers to the production, distribution, storage, and use of hydrogen at gigawatt scale.

The governance of MI is based on an "enabling framework", comprising several bodies. High-level leadership is provided by ministers from member countries (typically ministers of energy but also ministers of science, technology and innovation) meeting annually at Clean Energy Ministerial. The strategic guidance to foster the implementation of the initiative is provided by the MI Steering Committee, comprising representatives of member states. Core administrative functions are carried out by the distributed MI Secretariat provided by delegated officials from several member countries and the European Commission.

There are MI Sub-Groups focused on:

- Analysis and Joint Research Sub-Group collects and shares the collective knowledge, capabilities and resources of members to maximise impact across eight ICs;
- Business and Investor Engagement Sub-Group assists MI members in identifying opportunities and engaging the private sector;
- Ministerial Planning Team provides strategic and diplomatic oversight for the annual MI Ministerial.

The participation in the MI framework does not create any legally binding obligations for the MI member countries.

Sources and further information:

- Mission Innovation website – https://mission-innovation.net
- "Enabling Framework" for Mission Innovation (2016) – http://mission-innovation.net/wp-content/uploads/2016/06/MI-Enabling-Framework-1-June-2016.pdf
- Collaboration between MI and the Global Covenant of Mayors for Climate Change: https://www.globalcovenantofmayors.org/press/mission-innovation-gcom-collaboration/?utm_source=nyt&utm_medium=post&utm_campaign=MI

Case 3. Global AMR R&D Hub

The Global Antimicrobial Resistance Research and Development Hub (Global AMR R&D Hub) was launched on 22 May 2018 at the side event of the World Health Assembly in Geneva. The establishment of the hub was led by the German Federal Government in the framework of Germany´s G20 presidency in 2017. The G20 heads of state and government took the decision to intensify global collaboration in the fight against AMR. The Federal Ministry of Education and Research (BMBF) proposed to set up the Global AMR R&D Hub. The BMBF will provide up to EUR 500 million over the next ten years towards research to combat AMR.

The Hub aims to become a key actor with an integrating role in global R&D on AMR by bringing together governments and relevant foundations from different world regions, promoting the focus on AMR as one of the global R&D priorities and promoting high-level coordination and alignment of existing public and private funding to leverage investments in R&D on AMR on national and international levels. The collaboration is directly relevant for SDG 3 "Good health and well-being". The hub brings together 16 countries, the European Commission, two philanthropic foundations and four international organisations (as observers).[22]

The main objectives of the Hub are to:

- Inform high-level decision makers on AMR R&D investment pipelines in order to identify and prioritise R&D gaps and help focus high-level decision-making;
- Facilitate the efficient allocation of resources;
- Promote increased investments into push and pull incentives for AMR R&D in order to maximize the impact of national and international research activities;
- Foster international research collaboration among different partners globally, including industry and academia;
- Support the filling of product pipelines with priority candidates, using an appropriate mix of incentives, with a view to the development of deployable products, while recognizing the importance of access, prudent use, and stewardship;
- Inform policymakers on AMR R&D and keep attention on AMR at high political levels;
- Raise and maintain public awareness and visibility through communication of the work of the hub and its results.

The activities of the Global AMR R&D Hub include:

- Planning, designing and building an online Dynamic Dashboard to present all AMR R&D investments from the public and private sectors globally across the One Health continuum;
- Consulting with a Stakeholder Group, consisting of approximately 20 members from non-government organisations, civil society, industry, international research funding initiatives and academia, to advice the Hub on specific topics, including the Dynamic Dashboard;
- Working with the Market Analysis Expert Advisory Group to evaluate and determine the market potential of interventions addressing priority pathogens and indications, and
- Consulting widely with experts, other initiatives and organisations to promote the work of the Hub and to ensure there is no duplication of effort.

[22] The countries include Australia, Canada, China, France, Germany, India, Italy, Japan, The Netherlands, Norway, Russia, Spain, Switzerland, Turkey, United Kingdom, United States of America. The charities are Bill & Melinda Gates Foundation and Wellcome Trust.

The governance structure of the hub comprises the Board of Members, Stakeholder Group, Expert Advisory Groups and Secretariat. The Board is composed of one representative of each member. The Board is the only decision-making body of the hub; its members should have mandate to act and decide on behalf of their countries or organisations or be able to reach a decision within one month. The Secretariat is responsible for the implementation of the work plan under the direction of the Board of Members. For the first three years, the secretariat will be based in Berlin, at the German Center for Infection Research (DZIF).

The Hub strives to be run in an inclusive and open way, seeking feedback on its planned collaboration mechanisms. For example, it opened a survey on its draft Collaboration Framework to collect ideas on how it could work more effectively towards improving global coordination of AMR R&D. Feedback gathered through the survey will be discussed by the Board of Members and Stakeholder Group, and will be used for the development of an appendix outlining what collaboration mechanisms will be implemented under the Collaboration Framework. The Hub will be subject to an external evaluation to monitor progress towards its objectives and to inform any potential adaptations or changes.

Sources and further information:

- Global AMR R&D Hub webpage - https://globalamrhub.org

Case 4. ASEAN-India STI cooperation (WB)

ASEAN-India S&T Working Group (AIWGST)

ASEAN-India Science & Technology Collaboration started in 1996 with establishment of ASEAN-India S&T Working Group (AIWGST). The AIWGST was set up following the decision of the ASEAN-India Joint Cooperation Committee to make S&T one of the major topics of ASEAN-India relations.

The main objective of the AIWGST is to promote and intensify cooperation in the specific and technological activities between ASEAN and India and, in particular, to:

- Generate and promote development of scientific and technological expertise and manpower through joint programmes with India;
- Facilitate and accelerate the transfer of scientific and technological developments beneficial to ASEAN countries and India and to explore possibilities for future collaborations;
- Assess the current strengths of ASEAN and India in Science and S&T within the global context and explore ways to capitalise on these strengths/synergies; and
- Encourage the participation of the private sector in industry-relevant R&D activities.

The Working Group consists of representatives of the Indian Government (Department of S&T and Ministry of External Affairs), National Focal Points of the ASEAN Committee on Science and Technology (ASEAN COST), and the ASEAN Secretariat. The AIWGST meets every year to discuss joint cooperative programmes in S&T between ASEAN[23] and India; prioritise, approve, coordinate and review programmes and activities, including under the ASEAN-India S&T Development Fund; identify future areas for cooperation in S&T; and encourage the participation of the private sector in S&T activities.

ASEAN-India S&T Development Fund (AISTDF)

The collaborative S&T projects and activities between India and ASEAN were initially supported through ASEAN India Fund (AIF). In 2008, a dedicated USD 1 million ASEAN India S&T Development Fund (AISTDF)

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[23] Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam.

was established jointly by Department of S&T (DST) and Ministry of External Affairs (MEA) of India to support R&D projects and associated project development activities. In 2015, the AISTDF's endowment went up to USD 5million. The Fund is open to applicants from ASEAN member states and India.

The main objective of AISTDF is to use Science & Technology as tool for realisation of ASEAN-India partnership for peace, progress and shared prosperity. The activities and projects funded by AISTDF are to ASEAN-centred, action-oriented and aligned with the ASEAN Plan of Action on Science, Technology and Innovation (APASTI) 2016-2025.

The main objectives of ASEAN-India STI cooperation have three purposes:

- Encourage and promote cooperation in science, technology and innovation, including through joint research activity, and development on cross-sectoral areas such as health, communicable and emerging infectious diseases, environmental management, climate change adaptation and mitigation measures, agricultural technologies, alternative energy, biodiversity, food processing, advanced materials for development of value-added products, and space technology and applications;
- Encourage and promote cooperation in biotechnology including through capacity building and joint research and development for mutual benefit;
- Undertake activities and develop program / projects under the ASEAN-India Science and Technology Development Fund.

AISTDF has three main schemes: Research Training Fellowship (AI-RTF), Collaborative R&D and Innovation Platform (AIIP). Research Training Fellowship (AI-RTF) aims to promote mobility of scientists and researchers from the ASEAN member countries to India and to facilitate exchange of information and contacts between the scientists and researchers in the region. The scheme offers 50 two- to six-month fellowships per year (five per each ASEAN country). The fellowships have a broad disciplinary coverage but should be working on the topics relevant for APASTI.

Collaborative R&D projects should focus on topics relevant for APASTI and have to be put forward jointly by researchers in India and at least two ASEAN member countries. The duration of projects is up to two years. The priority areas of cooperation include bio-medical devices, agriculture and food science & technology (related to climate change adaptation technologies), ICT and Cyber Physical systems, as well as collaboration and partnership projects with ASEAN Centres and Networks.

The ASEAN-India Innovation Platform focuses on innovation and aims to turn ideas into solutions to common challenges of societal relevance. The platform focuses on three innovation dimensions: product innovation, social innovation and research innovation. The focus is in inclusive innovation, including low cost technologies, with a potential to bring social impact and address challenges of inclusive growth. The platform supports networking activities connecting innovators and innovation intermediaries from the region to share good practices, improve understanding of innovative business models and support technology transfer and commercialization of research results. It develops "innovation bank" with information on open-source innovations and technologies and expired and abandoned patents. The platform runs challenge awards for innovations addressing persisting social and environmental problems in the region and globally (e.g. waste management and reduction of non-recyclable waste).

The AISTDF is governed by a Governing Council composed of high-level representatives of DST, MEA and ASEAN. The Council meets at least once a year back to back with the meeting of the AIWGST to monitor and evaluate the on-going activities and approve the new activities for support under AISTDF with decisions made on a consensus basis. Any new collaborative programme to be supported under AISTDF needs to be first discussed and approved by the AIWGST.

Up to 90% funds of AISTDF are invested in scientific activities, project funding and programme whereas remaining 10% of the AISTDF cover administrative expenses, including day to day expenses of the Secretariat of AISTDF.

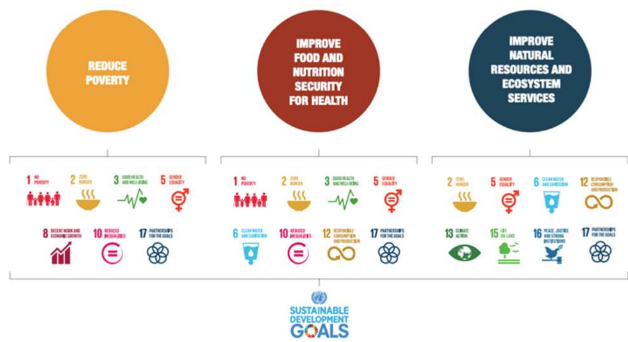
Sources and further information:

- ASEAN-India STI Cooperation: Innovation platform - https://aistic.gov.in/ASEAN/HomePage
- Innovation platform – Product Innovation: http://www.aseanindiapip.com
- Innovation platform – Social Innovation: http://www.indiaaseaninnovation.com/
- Innovation platform – Research Innovation: http://www.aseanindiaresinn.com/

Case 5. CGIAR Partnerships and innovation (WB)

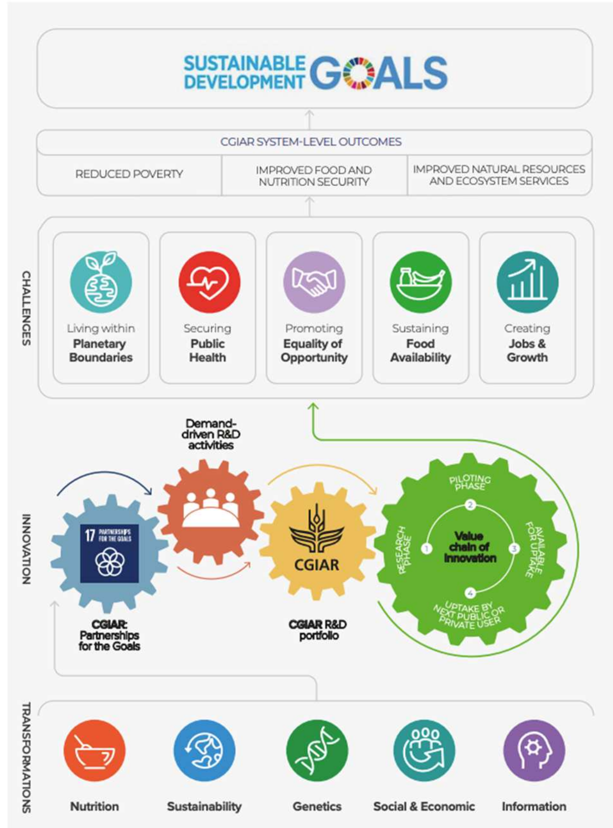
CGIAR, established in 1971, is a global publicly-led research partnership for research and development for sustainable agri-food systems in developing countries. CGIAR's mission is to advance agricultural science and innovation to enable poor people, especially women, to better nourish their families, and improve productivity and resilience, so they can share in economic growth and manage natural resources in the face of climate change and other challenges.

CGIAR is one of few challenge-led international STI organisations with an explicit intervention logic. CGIAR's second comprehensive Strategy and Results Framework (SRF) aligned key outcomes of CGIAR activities with the 2030 Strategy and the SDGs. It has placed its operations against a wider context of major global transformations and challenges to agro-food system (see Figures on the right).



The CGIAR goals contribute strongly to SDG 1, 2, 3, 5, 6,13 and 15 and moderately to SDG 8, 10, 12, 16 and 17.

The CGIAR Consortium obtained international organization status in 2012. In 2016, the 15 CGIAR Research Centres and Funders agreed on the CGIAR System Framework, setting up a governance for the organization with CGIAR System Council and a CGIAR System Organization (see CGIAR System Framework 2016).



The CGIAR System comprises the CGIAR centres, the funders, the System Management Board and the System Management Office, and the advisory bodies (Independent Science for Development Council, Internal Audit Function, Standing Panel on Impact Assessment).

Key actors in the CGIAR System include the following:

- CGIAR Centres are independent and autonomous organizations with their own governance structures, which focus on conduct, delivery and impact of the CGIAR research for development when working with CGIAR Partners within the CGIAR Strategy and Results Framework (SRF).
- The Funders provide guidance and financial resources for CGIAR activities. Representatives of Funders and developing countries meet as a System Council to keep under review the strategy, mission, impact and continued relevancy of the CGIAR System in a rapidly changing landscape of agricultural research for development.
- The governing and administrative bodies of the System Organization are the System Management Board and the System Management Office, respectively. The System Organization facilitates and oversees effective and efficient development and implementation of the CGIAR SRF. The System Organization enters into agreements with the trustee of the CGIAR Trust Fund, Funders, Centres and other relevant entities for funding CGIAR activities.

CGIAR works in close collaboration with multiple stakeholders, including national and regional research institutes, civil society, academia, development organizations and the private sector. The organisations have a local presence in more than 75 countries and had more than 1,500 active external partnerships in 2017. CGIAR's ambition is to use its partnerships and interfacing roles as well as the diversity of assets and skills to drive the global transformation towards more a sustainable agri-food system. CGIAR research program theories of change explicitly acknowledge the role of the private sector. CGIAR can make important contributions in the pre-competitive space for innovations that will eventually be taken up and spread by private firms.

The SRF considers partnership critical to the achievement of CGIAR's goals. CGIAR partnerships are to be guided by five principles:

- A common agenda: All partners must share a vision for change, including a common understanding of the problems and a joint approach to solving them.
- Shared measurement; Collecting data and measuring results across all locations ensures that efforts remain aligned and partners hold each other accountable.

- Mutually reinforcing activities: Partners should have distinct roles, which need to be coordinated through a mutually reinforcing plan of action.
- Continuous communication: Consistent and open communication lines are critical in order to build trust and ensure the realization of shared objectives.
- Backbone support: Creating and managing collective impact requires a designated entity with staff and specific skill sets, to serve as the backbone for the partnership.

Multi-stakeholder platforms (MSP) involve alliances of diverse stakeholders, often with broad objectives for knowledge sharing and action and hence important for delivery of outcomes and impact. Over the past two decades, there has been a rapid growth in CGIAR's involvement, particularly in two kinds of MSPs: locally-based innovation platforms and global MSPs, set up to address complex problems (CGIAR – IEA 2017). A recent evaluation found that "MSPs addressing global challenges have been important for engagement with multiple stakeholders including NGOs, Civil society organizations (CSOs), governmental and intergovernmental organizations" (ibid). It also concluded that "the selection and diversity of partnerships [CGIAR Centres and Research Programmes are involved in] respond well to the reform expectation to strengthen orientation of International Public Goods research towards development results." It added, however, that "CGIAR should make more effort to draw lessons from different partnership models, and thus to optimize its involvement, particularly in Minimum Support Prices. Centres and Common Pool Resources (CRPs) have been willing to work within a range of models to fit specific situations, and to experiment when necessary" (ibid).

Capacity development is a strategic enabler of impact for both CGIAR and its partners. CGIAR has a dedicated Capacity Development Framework. The Research Centres, CGIAR Research Programs, and networks help partners develop the skills and knowledge they need to take part effectively in global agricultural research programs, build and support international research networks and develop effective partnerships with civil society organizations and private sector entities. The system provides practical, hands-on mentorship in research laboratories and experiment stations, as well as in farmers' fields (e.g. BecA-ILRI – Nairobi-based Biosciences eastern and central Africa - International Livestock Research Institute, co-created by ILRI and the New Partnership for Africa's Development - NEPAD).

CGIAR has an annual research portfolio of just over USD 900 million with 11,000 staff. CGIAR provides a participatory mechanism for national governments, multilateral funding and development agencies and leading private foundations to finance some of the world's most innovative agricultural research. The CGIAR Trust Fund is a multi-Funder, multi-year mechanism that delivers financial resources for CGIAR research and key system functions. Funding to the CGIAR Trust Fund is channelled through three windows:

- Window 1 (W1) – Portfolio investments: funding allocated to the entire CGIAR portfolio of approved system-wide investments, prioritized and allocated by Funders collectively through the System Council – supporting CGIAR as a whole.
- Window 2 (W2) – Program investments: funding allocated by Funders individually to any component (CRP, Platform or initiative) of the system-wide portfolio as prioritized, defined and approved by the Funders collectively through the System Council; and
- Window 3 (W3) – Project investments: funding allocated by Funders individually to projects defined by the Funders themselves (with partners) and aligned with system-wide investments.

In 2018, the CGIAR approved the CGIAR System three-year Business Plan (2019-2021) which emphasizes the role of improved collaboration and closer partnerships both between the CGIAR Research Centres as well as between CGIAR and its delivery partners. Action 5 of the plan is to build centre alliances to pursue a strong strategic alignment and build synergies to reach critical mass in research programmes and improve engagement with strategic delivery partners. Action 6 seeks to enhance collaboration with delivery partners ranging from improving country level collaborations to deepening private sector collaborations (including system-level collaborations with multi-national companies) and improving relationships with Multilateral Development Banks.

Source: Total Trust Fund contributions in USD; CGIAR Trust Fund Dashboard (top 16 funders)

The Plan also foresees establishing the CGIAR Rome Hub. The four objectives of the hub include:

- A greater research engagement in global food security agenda and policy discussions in Rome;
- Scaling of research innovations through development and relief programs led by Rome-based institutions;
- Improved CGIAR connectivity to key delivery and funding partners;
- Greater CGIAR Center collaboration to support greater alignment and connectivity between participating Centres.

Sources and further information:

- The CGIAR's Strategy and Results Framework (SRF) 2016-2030 (2015) - https://www.cgiar.org/how-we-work/strategy/
- The CGIAR System three-year Business Plan 2019-2021 (2018) - https://storage.googleapis.com/cgiarorg/2019/02/CGIAR-Business-Plan-Web.pdf
- CGIAR webpages devoted to partnerships and collaborations - https://www.cgiar.org/how-we-work/strategy/partnerships/ and https://www.cgiar.org/partnerships-for-delivery/
- CGIAR System Framework (2016) - https://cgspace.cgiar.org/bitstream/handle/10947/4371/CGIAR%20System%20Framework%20-%20WEB.pdf
- CGIAR - IEA (2017), Evaluation of Partnerships in CGIAR, Rome, Italy: Independent Evaluation Arrangement (IEA) of CGIAR. See http://iea.cgiar.org/wp-content/uploads/2016/10/IEA-Evaluation-of-partnerships_Report.pdf

Case 6. The Joint Programming Initiative on Healthy and Productive Seas and Oceans – "JPI Oceans"

EU's JPI Oceans is an intergovernmental platform that strives to increase the impact of national investments in marine and Maritime research & innovation and skills. By joining forces, JPI Oceans focuses on long-term collaboration between EU Member States and Associated Countries and international partners, who invest in marine and maritime research. It is specifically dedicated to research on marine issues and will develop stronger long-term structures and partnerships to link marine research and marine environment policy.

JPI Oceans focuses on making better and more efficient use of national research budgets, which represent 88% of the research funding within Europe. One of JPI Oceans' goals is to develop joint research programmes in which countries can be involved on a voluntary basis (variable geometry). Participating countries also decide what contribution to make: this may include institutional, project-related or new funding. JPI Oceans promotes the strategic alignment and coordination of national R&D investments and best use of other funding streams. Some partners might fund only industry or only research institutes.

There should be at least two partners from two countries for each project.

JPI Oceans aims to add value by:

- avoiding fragmentation and unnecessary duplication,
- planning common and flexible initiatives,
- facilitating cooperation and foresight, and
- establishing efficient mechanisms for interaction and knowledge transfer between the scientific community, industry & services, and policymakers at high level in order to solve the grand challenges more effectively.

Data management: With respect to open research, data management, knowledge transfer and exploitation, JPI Oceans follows the recommendations and principles set out in of the "Voluntary Guidelines on Framework Conditions for Joint Programming in Research" (2010). It implements these on a case-by-case basis according to the needs of each specific action and the procedures of the funding organisations involved. Governance: a high-level Management Board (MB) runs JPI Healthy and Productive Seas and Oceans with representatives from each country with sufficient authority to agree on joint action plans and potential funding initiatives across Europe. The Management Board mandates an Internal Advisory Committee to execute the decisions taken by the Management Board and to supervise the different JPI activities.

The secretariat is responsible for the day-to-day management of JPI Oceans. The secretariat assists the Management Board and the Internal Advisory Committee. In addition, the secretariat ensures the necessary logistical coordination and communication among different bodies of the management structure and additional working groups.

Monitoring and Evaluation: The evaluation approach laid down in JPI Oceans' strategies, and plans includes a system for monitoring key developments. The monitoring is based on tagging key actions and activities in line with those identified in the Strategic Research and Innovation Agenda, the Implementation plan and the Operational plan, and thereby allow building a database of activities, inputs and outputs. The monitoring serves two purposes: Firstly, to ensure real-time information to support ongoing decision making in the governing bodies of the partnership, and secondly to ensure the build-up of information and data for dedicated evaluation efforts.

Sources and further information:

- The JPI Oceans webpage - https://www.jpi-oceans.eu/

Case 7. The IMI and the fight against Ebola

Innovative Medicines Initiative (IMI) is a Joint Undertaking between the EU and the European Federation of Pharmaceutical Industries Associations (EFPIA). It is the world's largest public–private initiative for health research and innovation. The initiative aims at boosting pharmaceutical innovation in Europe and ultimately improving health by speeding up the development of innovative medicines, vaccines and medical technologies, particularly in areas where there is an unmet medical need.

During the 2014-16 outbreak EUR 215 million in research funding for Ebola and related viruses were mobilised by the Innovative Medicines Initiative (IMI).The Innovative Medicines Initiative (IMI) launched the first eight projects of its Ebola+ programme, to accelerate all aspects of vaccine development and manufacturing as well as deployment and compliance with vaccine regimens and diagnostics. The eight projects were selected from proposals submitted under IMI's first Ebola+ Call for proposals, which was launched in November 2014.

The projects will have a total budget of EUR 215 million, part of which comes from Horizon 2020, the EU's research and innovation programme, and part of which comes in the form of in-kind contributions from the European Federation of Pharmaceutical Industries and Associations (EFPIA) partners in the projects. Of the eight projects, three will focus on the development of Ebola vaccines; one will work on scaling up vaccine manufacture; one will develop strategies to promote compliance with vaccine regimens; and three aim to develop rapid diagnostic tests that can be used at the point of care and at major infrastructures like airports.

Since 2014, there has been ongoing development of vaccine candidates for Ebola through the IMI Ebola+ programme. As a result of funding from the EU and other international partners, a vaccine (rVSVΔG-ZEBOV-GP) now exists that demonstrated some effectiveness in humans during the Ebola outbreak in West Africa. This vaccine is now being deployed in Democratic Republic of Congo to gather more evidence of its effectiveness, and to help combat the current outbreak. A second vaccine (Ad26.ZEBOV/MVA) is currently being assessed by the WHO for approval for use in the current outbreak, and with the support of EU funding 1.6 million doses have already been produced and stockpiled. This vaccine has the advantage that it can be easily deployed without the need for ultra-cold storage.

Under the IMI Ebola+programme, the Mofina project developed a portable device which can test for deadly Ebola in 75 minutes or less, eliminating the need to take suspected Ebola patients to treatment centres far away of their communities. The Mofin project involves universities, research organisations, public bodies, non-profit groups including:

- Bernhard-Nocht-Institut Fuer Tropenmedizin, Hamburg, Germany
- Department Of Health, Leeds, United Kingdom
- Foundation For Innovative New Diagnostics, Geneva, Switzerland
- Istituto Nazionale Per Le Malattie Infettive Lazzaro Spallanzani-Istituto Di Ricovero E Cura A Carattere Scientifico, Rome, Italy
- Small and medium-sized enterprises (SMEs) and mid-sized companies (< EUR500 m turnover)
- Altona Diagnostics GMBH, Hamburg, Germany
- Non-EFPIA companies
- Alere Technologies GMBH, Jena, Germany

Governance: IMI is governed by a board composed of ten members equally representing the two Founding Members: five from the European Commission, representing the EU, and five from EFPIA, representing the research-based pharmaceutical industry in Europe. The Governing Board is the main decision-making body of IMI. In particular, it adopts the Annual Work Plans that identify calls for proposals, with call topics from which collaborative projects are being selected by panels of independent experts. Two advisory bodies to the Governing Board have been established: (1) a Scientific Committee with leading experts from a range of fields, who participate in their individual capacities; and (2) a States Representatives Group with members from the EU Member States and the countries associated with Horizon 2020, who represent their national governments.

Evaluation: The evaluation of the first phase of IMI operating under FP7, as well as an interim evaluation of the ongoing IMI2 initiative (for the period 2014–2016) operating under Horizon 2020. Two corresponding reports were published on 6 October 2017 [10, 11], as well as an overall interim assessment of the seven Joint Undertakings1 operating under Horizon 2020. The experts concluded that "the reasons to create a public–private partnership to strengthen the European pharma industry were valid and the goals were justified”, and that the partnership had “realised a number of very promising results”. The experts, however, recommended that (1) stronger efforts be made to attract and integrate other industries besides pharmaceutical industries in the collaborative projects; (2) more efforts be deployed to attract more SMEs; (3) access to project outcomes be broadened and the sustainability of project results be improved, to increase impact; (4) better Key Performance Indicators of the initiative be developed; and (5) Intellectual Property (IP) policy be reviewed to make it more flexible, allowing negotiations on exclusive rights. In November 2017, the IMI2 Governing Board agreed on an Action Plan addressing these recommendations in IMI2, and actions are now underway. A new framework of Key Performance Indicators has already been adopted, and activities designed specifically to engage more non-pharmaceutical industries and SMEs have been initiated.

Sources and further information:

- The IMI webpage on Ebola+ Programme - https://www.imi.europa.eu/projects-results/project-factsheets/ebola
- Faure, Jean-Emmanuel et. al. (2018). *The European Innovative Medicines Initiative: Progress to Date* in Pharmaceutical Medicine (2018) 32:243–249 https://doi.org/10.1007/s40290-018-0241-y

Annex V. Key policy considerations for international STI collaborations for the SDGs

Pillars	Governance and institutional setting	STI instruments and collaboration mechanisms	Learning, monitoring and evaluation
Cross-cutting considerations	Central role of STI for accomplishing the SDGs in international deliberations on international activities and investments in the SDGs - Multi-stakeholder engagement from priority setting to evaluation of international collaboration - Institutional design ensuring a level-playing field for all partners and avoiding capture - Funding models allowing to scale and align investment needed to address the SDGs	- Mix of complementary instruments and collaboration mechanisms addressing three models of collaborations - Searching for greater consistency, coordination and coherence of national and international STI policy mix to align international STI collaborations with the SDGs	- Integrating monitoring and evaluation as an integral element of all international STI collaborations for the SDGs - Adjust evaluation systems, including methodologies and metrics, to the SDGs - Build a shared evaluation approach accepted by all partners engaged in collaborations - Agree on a shared theory of change and impact pathways towards achieving the SDGs expected to be triggered by international STI collaborations
Pillar 1: Building up national STI capabilities to address the SDGs - Support development of STI human capital, institutional capacity, infrastructures and domestic linkages to address the SDGs	- Engaging local stakeholders to ensure that priorities of STI collaboration are shared and accepted by key communities - Revisiting ODA to consider the role of STI in achieving the SDGs, including harnessing benefits and managing risks of disruptive technologies - Improving national STI institutional setting to better address local societal challenges and the SDGs - Country-level alignment of ODA and other sources of funding with the SDGs	- Strategic framework and governance (e.g. active engagement of developing countries in international STI policy fora and multi-stakeholder platforms) - STI capacity building (focused on government and other key actors in STI national system) - Direct financial support to STI	- Developing strong national and local evaluation components focused on STI - Building up M&E and policy learning capacity in STI policy making and ODA specifically focused on the SDGs and challenge-led policies
Pillar 2: Boosting international STI flows for the SDGs - Support international flow of knowledge and technologies - Support cross-country collaborations to create STI relevant for SDGs	- Improving international inclusion, engagement and coordination of key STI actors to identify and remove international bottlenecks to international knowledge and technology flows of key relevance for the SDGs - Extending STI agendas and priority setting to better acknowledge the role of sharing applied knowledge and innovations - Improving international consistency and coordination of STI activities focused on the SDGs - International alignment and streamlining of ODA and other international funding with the SDGs	- Strategic frameworks and governance (e.g. revision of international IPR agreements to unlock knowledge sharing in areas relevant for the SDGs) - International STI platforms and infrastructures (including shared databases, open science platforms), - STI capacity (e.g. mobility of researchers, international capacity development programmes for the SDGs) - Direct financial support to collaborative STI initiatives targeting the SDGs - Streamlining existing ODA and international STI funding to address the SDGs more effectively	- Develop international principles and frameworks in monitoring and evaluation of STI for the SDGs to be applied in bilateral and multilateral ODA and international STI collaborations - Ensure that international STI databases have relevant data to be used as context indicators or international benchmarks for assessing progress towards the SDGs - Build international communities of practice to enable international policy learning and develop shared understanding and practices to be applied in M&E systems

Pillars	Governance and institutional setting	STI instruments and collaboration mechanisms	Learning, monitoring and evaluation
Cross-cutting considerations	Central role of STI for accomplishing the SDGs in international deliberations on international activities and investments in the SDGs - Multi-stakeholder engagement from priority setting to evaluation of international collaboration - Institutional design ensuring a level-playing field for all partners and avoiding capture - Funding models allowing to scale and align investment needed to address the SDGs	- Mix of complementary instruments and collaboration mechanisms addressing three models of collaborations - Searching for greater consistency, coordination and coherence of national and international STI policy mix to align international STI collaborations with the SDGs	- Integrating monitoring and evaluation as an integral element of all international STI collaborations for the SDGs - Adjust evaluation systems, including methodologies and metrics, to the SDGs - Build a shared evaluation approach accepted by all partners engaged in collaborations - Agree on a shared theory of change and impact pathways towards achieving the SDGs expected to be triggered by international STI collaborations
Pillar 3: Brokering international STI collaborations for SDGs - Broker international coalitions to use STI to address the GPGs - Broker coalitions to assess impact of disruptive technologies and to develop appropriate regulations as well mitigation and adaptation mechanisms	- Broker global coalitions and multi-stakeholder partnerships to use STI to deliver GPGs such as climate change, oceans, biodiversity - Developing joint international agendas and strategies for global STI initiatives and investments for the SDGs - Shifting the focus of international STI collaboration towards transformative system innovations - Innovating existing and setting up new modes of global STI governance, including building new capabilities and mandates for global action for the GPGs - Establishing innovative funding models mobilising investments in STI (e.g. blended finance funds)	- Global strategies to implement priority actions for the SDGs (e.g. transformative STI agendas and missions) - New international treaties and legal frameworks establishing binding commitments, rules and standards to enable transition towards the SDGs (e.g. environmental regulations with binding targets). - Sustaining and building new international large-scale research infrastructures such as CERN) Joint economic instruments, including international challenge-led STI programmes focused on the SDGs (e.g. Horizon Europe in the EU) - Alignment of public procurement and fiscal policies to favour STI focused on the SDGs (e.g. carbon tax)	- Developing global foresight and policy intelligence capacities catered for supporting design and implementation of Pillar 3-type of actions

Source: Authors