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The state of science, technology and innovation in the least developed countries

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Foreword

As the decade of the Istanbul Programme of Action draws to a close, and with the COVID-19 pandemic having disrupted the development path of most countries, there is a pressing need to take stock of persisting and emerging challenges for least developed countries to ensure no one is left behind. The pandemic has disproportionately affected these countries, further exposing their limitations in the areas of science, technology and innovation and exacerbating the technological gap between them and other nations.

Least developed countries face many diverse challenges, some of which are persistent and typical of resource-poor and underdeveloped economies. For example, economic vulnerability, poor environmental resilience, structural weaknesses, poor job creation, and resource constraints fall into this category. In addition, almost all least developed countries share one common factor: the limited development of their technological capabilities. The past two years have reinforced the importance of technological learning and upgrading and the longer-term need to build innovation capacities to support countries' own economic and structural transformation. More fundamentally, the pandemic has demonstrated that when someone is left behind due to lags in technological development, everyone is held back.

In this respect, the report by the Technology Bank addressing the state of science, technology and innovation in the least developed countries is a timely and important contribution to our understanding of the progress made by the 46 least developed countries in transferring technologies and building science, technology and innovation capacities. Even beyond the COVID-19 setback, structural impediments and inequality persist in these countries, while significant rural–urban gaps also continue to impact people's livelihoods.

Women in the least developed countries remain significantly under-represented across science, technology and innovation, particular in areas such as technology usage and development, engagement with connectivity, scientific publications and patent registration. It is essential that these countries recognize the contribution women can make to science and the importance of attracting and retaining such talent to ensure inclusive development. For many of them, particularly small islands or landlocked states, the threat posed by climate change is putting people's ability to continue living on their land and in their homes at risk. Ensuring that these countries are supported in addressing these challenges remains a top priority and the role of advancing science, technology and innovation for mitigation and adaption, as well as to ensure sustainable industrial development, cannot be underestimated.

The overarching objective of the Technology Bank is to assist least developed countries in building their science, technology and innovation capacity to foster the structural transformation of their economies, eradicate poverty and promote sustainable development. Long-term productivity upgrading, economic development and job creation, as well as addressing societal challenges, are all dependent on sustainable and strong science, technology and innovation systems. This report is a special publication on the state of science, technology and innovation in the least developed countries prepared for the Fifth United Nations Conference on the Least Developed Countries (LDC5). It presents a comprehensive overview of the relevance of science, technology and innovation in the least developed countries, maps the current state, highlights insights and best practices through country deep dives and recommends the way forward for science, technology and innovation development in these countries.

This is a critical time for realizing these countries' collective ambitions of building better, more resilient, sustainable and equitable economies and societies. It is important to ensure that they are well equipped to participate in, sustain and benefit from the ongoing and upcoming period of deep technological transformation.

The international community is responsible for promoting joint efforts to support least developed countries to build the scientific and technological foundations they need for their long-lasting development in the Decade of Action and beyond. This is necessary to meet the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) and ensure that no one is left behind.

Taffere Tesfachew
Acting Managing Director

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Acronyms

AfDB	African Development Bank
ASEAN	Association of Southeast Asian Nations
AUDA-NEPAD	African Union Development Agency
EVI	Economic Vulnerability Index
FDI	foreign direct investment
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GERD	Government expenditure on research and development
GISAID	Global Initiative on Sharing Avian Influenza Data
HAI	Human Assets Index
ICT	information and communications technology
IPoA	Istanbul Programme of Action
ITU	International Telecommunication Union
LDC	least developed country
MSMEs	micro, small and medium enterprises
NGO	non-governmental organization
OECD	Organisation for Economic Co-operation and Development
R&D	research and development
SDGs	Sustainable Development Goals
STEM	Science, Technology, Engineering and Mathematics
STI	science, technology and innovation
STISA-2024	Science, Technology and Innovation Strategy for Africa 2024
TFM	United Nations Technology Facilitation Mechanism
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environmental Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNICEF	United Nations Children's Fund
UN-OHRLLS	United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States
VPoA	Vienna Programme of Action
WHO	World Health Organization
WIPO	World Intellectual Property Organization

1. Introduction: the high-level publication on science, technology and innovation in the least developed countries

This introductory chapter considers the context of this inaugural high-level publication on science, technology and innovation (STI) in least developed countries, and the creation of the United Nations Technology Bank through the Istanbul Programme of Action (IPoA) to address it. The report uses the definition of STI adopted from the *Guidebook for the Preparation of Science, Technology and Innovation (STI) for the Sustainable Development Goal Roadmaps* that differentiates between three domains – science, technology and innovation – with distinct actors, linked by strong relationships and the national innovation systems framework. The chapter then considers the criteria for inclusion in the least developed country category, and the thresholds for graduation from this status.

Leaving no one behind is the central, transformative promise of the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs). Ensuring this occurs in the least developed countries presents a formidable challenge. Forty-six countries are currently classified as least developed countries, because they are low-income countries that face severe structural impediments to achieving sustainable development, have low levels of human assets and are vulnerable to economic and environmental shocks.[1] STI is instrumental in meeting the challenges faced by least developed countries in achieving sustainable economic and social development to uplift the lives of their people.

> **Building the national capacity for STI in the least developed countries will contribute significantly to achieving the goals of eradicating widespread poverty, removing structural constraints, enabling economic growth and supporting sustainable development for the nearly billion people living in these countries.**

This requires building the productive, human and knowledge capacities of least developed countries to overcome their structural challenges and address their specific sustainable development needs. Several bodies within the United Nations system recognize the importance of dedicated and coordinated actions for building capacities, coupled with the transfer of much-needed technologies to least developed countries on voluntary and mutually agreed terms and conditions.[2]

1.1 United Nations mobilization to facilitate innovation and technology diffusion

The IPoA for the Least Developed Countries for the Decade 2011–2020 was adopted in 2011 at the fourth United Nations Conference on the Least Developed Countries. A major outcome of this Conference was the call for the establishment of the United Nations Technology Bank for Least Developed Countries (hereinafter Technology Bank) for supporting STI development in these countries. Most international organizations and United Nations organizations have focused their activities on developing countries, and not specifically on those that are least developed; the Technology Bank was set up specifically to address this gap.

During the decade 2011–2020, the IPoA set several specific goals for least developed countries, and laid the foundations for their cooperation with the international community to fulfil the Millennium Development Goals, which later became the SDGs. A key principle created by the IPoA was the need for self-ownership, stressing that the primary responsibility for development lies with the least developed countries themselves. It also stressed the need for a balance between the State and market considerations in the development process. Furthermore, it called for an integrated approach in which the development process in least developed countries should be viewed in a comprehensive and holistic manner.

1 United Nations Department of Economic and Social Affairs (UN DESA), "Least developed countries (LDCs)", no date. Available at https://www.un.org/development/desa/dpad/least-developed-country-category.html (accessed on 16 December 2021).
2 United Nations Secretary-General's High-Level Panel on the Technology Bank for the Least Developed Countries, *Feasibility Study of the United Nations Technology Bank for the Least Developed Countries* (2015).

The report of the Secretary-General on the implementation of the Programme of Action for the Least Developed Countries for the Decade 2011–2020 noted that "The Technology Bank for the Least Developed Countries has an important role to play in advancing science, technology and innovation, as well as in bridging the digital divide and contributing to COVID-19 response and recovery".[3] On the implementation of the key STI priorities of the IPoA, progress in the ratio of research and development (R&D) expenditure as a share of gross domestic product (GDP) was 0.6 per cent or less between 2011 and 2017. Citizens of the least developed countries filed only 1,536 patents in 2018 and published only 11 journal articles for every million people in 2018, a slight increase from 6 in 2011.

The Technology Bank was officially established in 2016 by the United Nations General Assembly and became operational in 2018.

> **This marked the successful achievement of SDG Target 17.8, "Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology".**

The Technology Bank has five specific objectives:

1. (a) To strengthen the science, technology and innovation capacity of least developed countries, including the capacity to identify, absorb, develop, integrate and scale up the deployment of technologies and innovations, including indigenous ones, as well as the capacity to address and manage intellectual property rights issues
2. (b) To promote the development and implementation of national and regional science, technology and innovation strategies
3. (c) To strengthen partnerships among science, technology and innovation-related public entities and with the private sector
4. (d) To promote cooperation among all stakeholders involved in science, technology and innovation, including researchers, research institutions and public and private sector entities, within and between least developed countries, as well as with their counterparts in other countries
5. (e) To promote and facilitate the identification and utilization of and access to appropriate technologies by the least developed countries, as well as their transfer to the least developed countries, while respecting intellectual property rights and fostering the national and regional capacity of the least developed countries for the effective utilization of technology in order to bring about transformative change

3 United Nations, A/75/72–E/2020/14, p. 7.

The Technology Bank implements projects and activities in the least developed countries and serves as the focal point to strengthen their STI capacity and as a knowledge hub connecting the STI needs of least developed countries, available resources and actors who can respond to these needs. This is a major step in advancing the efforts of least developed countries. Its activities include producing STI reviews and Technology Needs Assessments in selected least developed countries. As of May 2022, Technology Needs Assessments were commissioned in Bangladesh, Benin, Bhutan, Burkina Faso, Cambodia, the Democratic Republic of the Congo, Djibouti, The Gambia, Guinea, Kiribati, Lesotho, Liberia, Malawi, Mozambique, Nepal, Rwanda, Sierra Leone, Timor-Leste, Uganda and Zambia. Technology Needs Assessments commenced in Afghanistan and Sudan but were suspended due to the changing political conflict.

The Addis Ababa Action Agenda of the Third International Conference on Financing for Development, adopted in 2015,[4] emphasized that STI play a major role in tackling the barriers faced by developing countries, particularly the least developed countries. One of the main components of this Agenda specifically concerned STI and capacity-building. It emphasized the importance of transfer of technology in the development and diffusion of new innovations, including the capacity of least developed countries to apply and absorb innovations where there is a digital divide, uneven innovative capacities and a lack of access to technology. It further encouraged voluntary patent pooling, the introduction of new business models to increase access to technology, and initiatives that could increase knowledge-sharing between different stakeholders. It also called for multinational companies to be better linked to domestic private sectors to facilitate mutual technology development and technology transfer on mutually agreed terms.

To support the implementation of its recommendations, the Addis Ababa Action Agenda created the Technology Facilitation Mechanism (TFM), as announced by the 2030 Agenda for Sustainable Development. The TFM is made up of a United Nations Inter-Agency Task Team on STI for the SDGs (IATT), a multi-stakeholder STI forum and an online platform for sharing information on STI initiatives, mechanisms and programmes. Figure 1 summarizes the key United Nations mechanisms for STI, and maps these onto the main channels for engaging stakeholders in the United Nations process that should be considered for STI-focused development in the least developed countries.

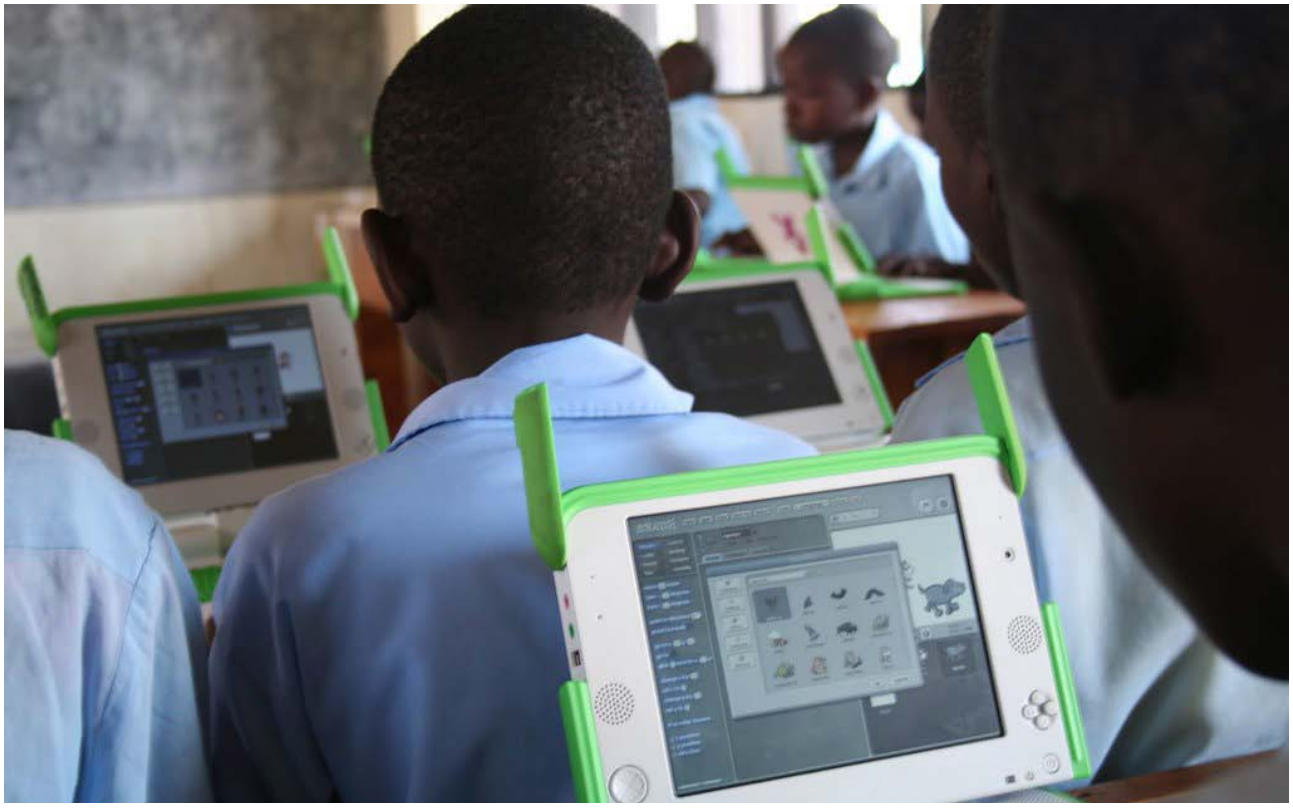
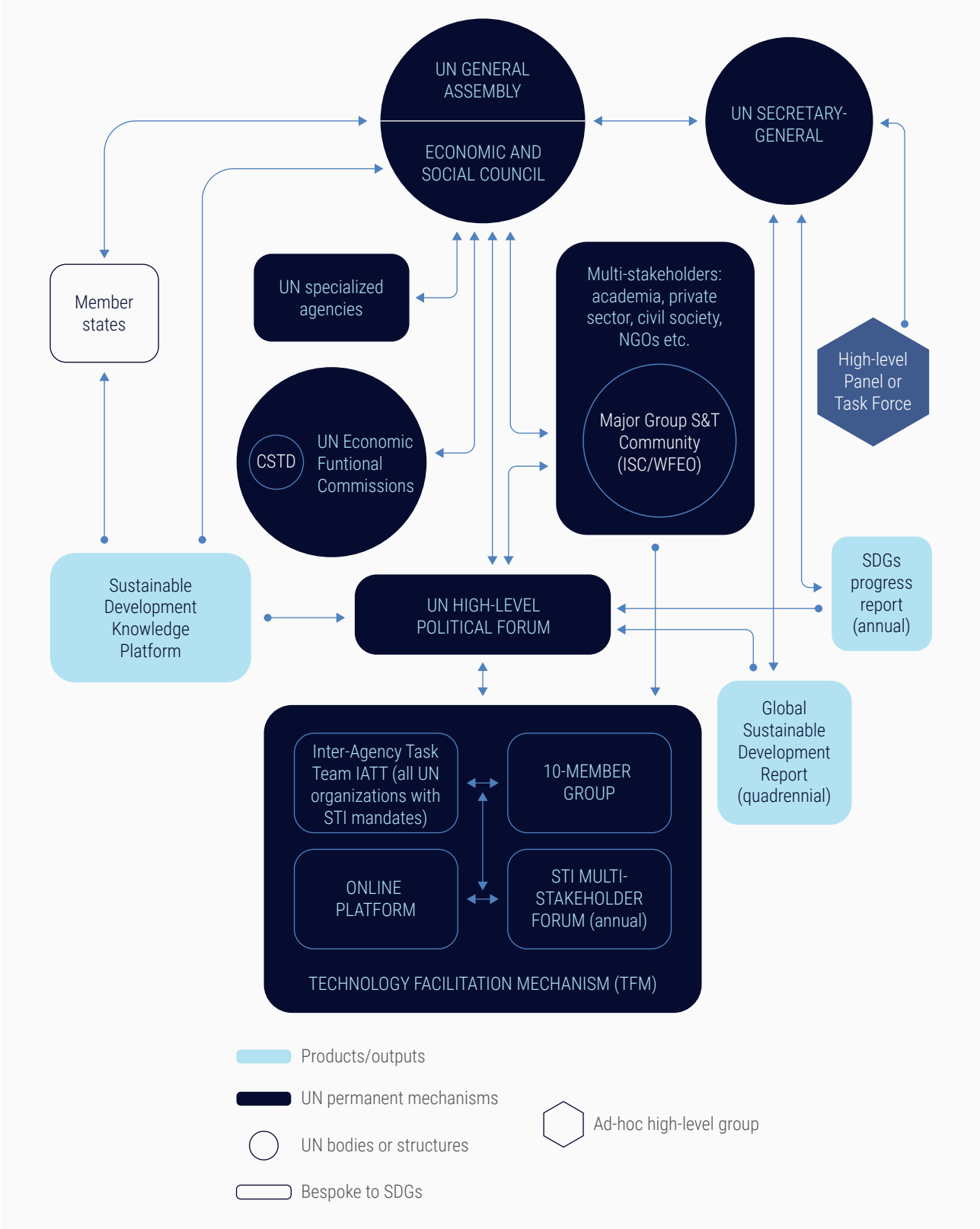


Photo credit: cellanr on Flickr

4 United Nations, *Addis Ababa Action Agenda of the Third International Conference on Financing for Development* (2015).

Figure 1. Mapping key United Nations mechanisms on STI under the 2030 Agenda for Sustainable Development



Source: United Nations Inter-Agency Task Team on Science, Technology and Innovation for the SDGs and European Commission, Joint Research Centre, *Guidebook for the Preparation of Science, Technology and Innovation (STI) for the Sustainable Development Goal Roadmaps* (Luxembourg, Publications Office of the European Union, 2021). Adapted from InterAcademy Partnership, *Improving Scientific Input to Global Policymaking, with a focus on the UN Sustainable Development Goals: Report* (Trieste, 2019). Note: CSTD stands for United Nations Commission on Science and Technology for Development. ISC/WFEO stands for International Science Council/The World Federation of Engineering Organizations.

The Fifth United Nations Conference on the Least Developed Countries will take place in two parts: the first in New York, United States of America, in March 2022 and the second in Doha, Qatar, in March 2023. Progress on IPoA priorities will be reviewed, and agreements on the commitments of the Doha Programme of Action (adopted during the first part of the LDC5 conference on 17 March 2022 and endorsed by the General Assembly through resolution A/76/L.47 on 1 April 2022) will be made. The Technology Bank's activities in mainstreaming STI for development within least developed countries require renewed commitment in this next decadal action plan. To leverage the power of STI against development challenges, and to achieve SDG targets, the "zero draft" of the Doha Programme includes targets and actions in the following key areas:

- Access to modern technologies for sustainable development, which requires building human capital, infrastructure and institutions to reap the benefits of the Fourth Industrial Revolution;
- Recovery from the COVID-19 pandemic and building resilience against emerging challenges and future systemic shocks and crises
- Promoting private sector engagement, digitization and broadband connectivity to achieve both basic infrastructure development and human capital accumulation as elaborated in the Secretary-General's Roadmap for Digital Cooperation, and its vision of a more inclusive, equitable and safe digital future for all[5]

This Technology Bank high-level publication aims to document and showcase the relevance of STI in the least developed countries, including:

- The relevance and state of STI in least developed countries (chapter 2)
- The main challenges faced by and opportunities for least developed countries regarding STI (chapter 3)
- The role of the regional and international community for STI development (chapter 4)
- Best practices from national STI systems (chapter 5)
- The future role of the Technology Bank in facilitating the development of STI in least developed countries (chapter 6)
- The business case for STI in least developed countries and a way forward for international organizations, donors and partners to support, and national Governments to take ownership of, STI in least developed countries (chapter 7)

The report is based on an extensive literature review (see Appendix 1), 14 interviews with high-level stakeholders (see Appendix 2), novel data on STI in the least developed countries (Appendix 3 and Appendix 4), and a survey of the STI ecosystems of the 46 least developed countries conducted from June to September 2021 (Appendix 5). Therefore, a large base of quantitative and qualitative information on STI in the least developed countries and its relevance was created in the production of this report, which may serve as a baseline for future publications.

The following two sections elaborate the definitions of STI and of least developed country status that will be used in this report.

1.2 Definitions of science, technology and innovation

The definition of STI adopted in this report is from the *Guidebook for the Preparation of Science, Technology and Innovation (STI) for the Sustainable Development Goal Roadmaps*,[6] that differentiates between three domains (science, technology and innovation) with distinct actors.[7]

5 United Nations Secretariat, *Draft Doha Programme of Action for Least Developed Countries: Note by the Secretariat*, 3 March 2022. Available at https://digitallibrary.un.org/record/3959499?ln=en. Accessed on 25 May 2022.
6 IATT, *Guidebook for the Preparation of Science, Technology and Innovation (STI) for the Sustainable Development Goal Roadmaps* (Luxembourg, Publications Office of the European Union, 2021).
7 For another definition, see Organisation for Economic Co-operation and Development (OECD) and Eurostat, *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation,* 4th ed. (Paris and Luxembourg, OECD Publishing and Eurostat, 2018).

Definitions in Box 1 highlight that science is the basic pursuit of knowledge about the natural and social world, while technology is the practical application of this knowledge to solve real world problems, and innovation refers to the diverse ways how new goods and services are produced based on new technologies or business/organizational models.

Box 1. Concepts and definitions of science, technology and innovation

Science is the pursuit of knowledge through the systematic study of the structure and behaviour of the physical and natural world and societies. Scientists or researchers are the key actors, often organized and represented through academies of sciences, professional societies, universities and other public or private research institutions. Governments typically have a responsible ministry overseeing science policies and funding agencies which administer research programmes.

Technology is the practical application of knowledge for a given end. Publicly funded scientists conducting applied research, as well as private sector scientists, engineers and product/service developers, are the key actors in developing and applying new technologies. A wider range of actors in industries and government ministries disseminate, adopt or adapt existing technologies in fields such as the agriculture, health, energy, education, defence, infrastructure and environmental purposes.

Innovation refers to a new way of producing, delivering or using goods and services, based on new technology, business models or forms of economic or social organization. While also applicable to public administration and service delivery, innovation so far has largely been a private sector undertaking by industries and entrepreneurs, farmers and individuals who develop better ways of producing or using goods and services. Today, the appearance of new social and community-based innovations (such as indigenous solutions) calls for a fresh understanding of this phenomenon.

Source: Guidebook for the Preparation of Science, Technology and Innovation (STI) for the Sustainable Development Goal Roadmaps.

The report also refers to the concept of STI ecosystems. Scientific literature, as well as donor policy analysis, have largely called for the use of the expanded concept of the national innovation system to both describe the existing systems and target efforts towards structuring a system in developing countries. Broadly, referred to as the system of organizations and individuals, and their interdependent relationships, who impact or are impacted by innovations originating or deployed.[8]

The national innovation system was built on the observation that a "linear model", in which scientific research directly contributes to technology and innovation, did not correspond to reality. The national innovation system framework regards technology and innovation as being co-produced by networks of actors, and therefore is potentially being stimulated anywhere in the system. Figure 2 provides a conventional representation of national innovation system components, which include the research and higher education system, the production system, the links between the two and various other contextual conditions, including demand, innovation infrastructures and framework conditions, as well as government and governance more broadly.

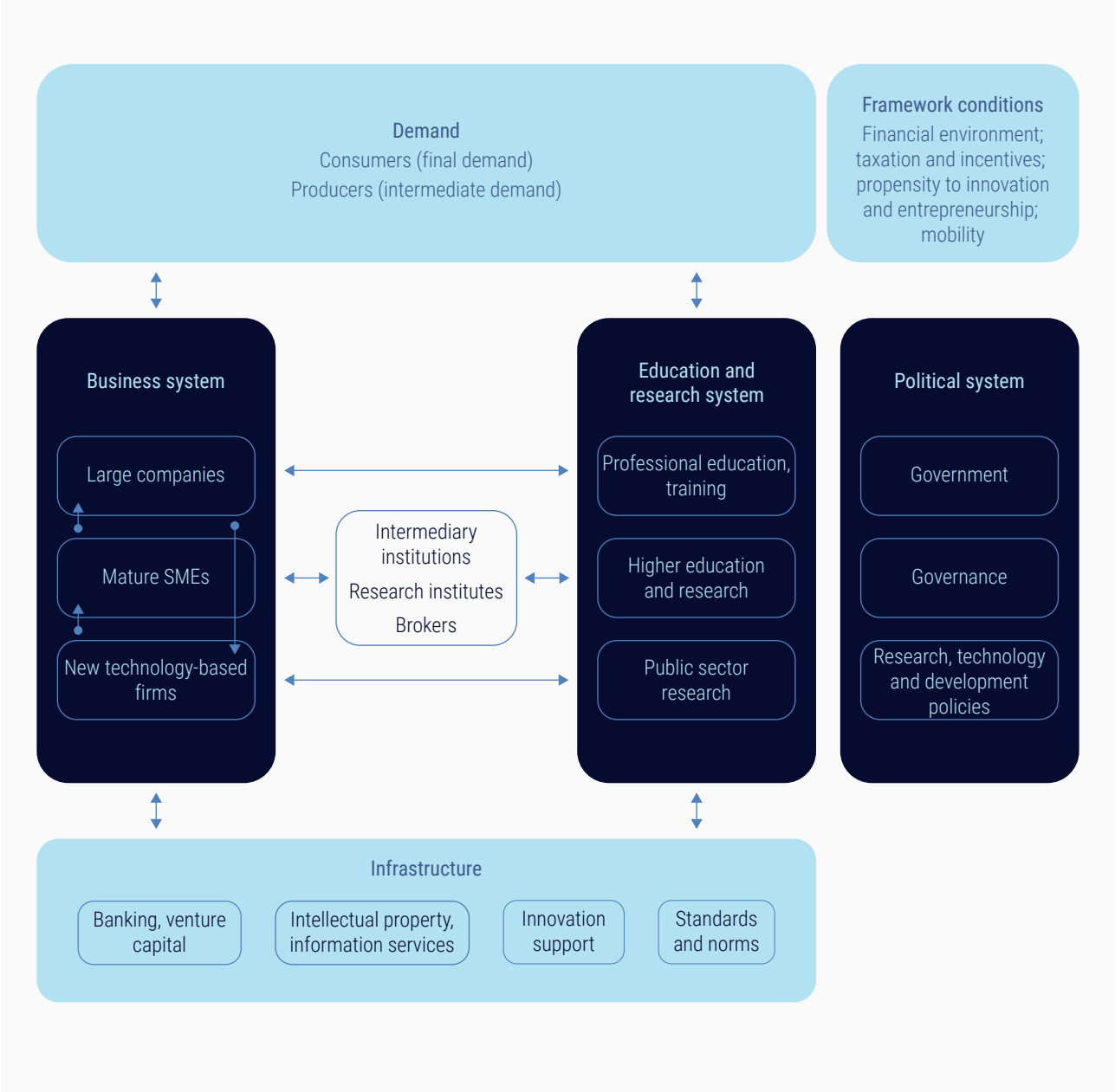
The interdependence of the various components implies that a well-functioning national innovation system needs every subsystem to work at a reasonable level of efficiency and effectiveness; since innovation is largely co-produced, the links between the components also need to function well. Hence, the policy mix should be designed in a way that achieves a balance among the different components and reinforces the mechanisms

8 Christopher Freeman, *Technology Policy and Economic Performance: Lessons from Japan* (London, Pinter, 1987); Bengt-Åke Lundvall, *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning* (London, Pinter, 1992); Richard R. Nelson ed., *National Innovation Systems: A Comparative Analysis* (Oxford, Oxford University Press, 1993).

between components. A key example is "absorptive capacity",[9] which is the ability to use internal R&D capabilities to understand, internalize and use knowledge, technologies and innovations produced by others in the national innovation system.

The development of STI ecosystems within the least developed countries is emergent, and has the potential to transform their development trajectories if approached systematically.

Figure 2. National innovation system framework



Source: Stefan Kuhlmann and Erik Arnold, "RCN in the Norwegian research and innovation system", Background Report No. 12 in the Evaluation of the Research Council of Norway (Oslo, Royal Norwegian Ministry of Education, Research and Church Affairs, 2001).

9 Wesley M. Cohen and Daniel A. Levinthal, "Absorptive capacity: a new perspective on learning and innovation", *Administrative Science Quarterly*, vol. 35, No. 1 (March 1990).

1.3 Definition of least developed country status and graduation process

The least developed countries category was established in 1971 by the United Nations; since then, only six countries have graduated from the category (i.e. have left the group of least developed countries). The category is revised every three years by the United Nations Committee for Development Policy (UNCDP), a subsidiary body of the United Nations Economic and Social Council (ECOSOC). The requirements for graduation from least developed country status is overseen by the UNCDP, and progress is continuously monitored after graduation from the category. The identification of least developed countries is currently based on three criteria: income, human assets and economic and environmental vulnerability (see Box 2). The latter two are measured by two indices of structural impediments, the Human Assets Index (HAI) and the Economic Vulnerability Index (EVI).

In the review process, the UNCDP determines threshold levels on each of the three criteria to identify the countries to be added to the category in recognition of their structural challenges, or graduation from the category in recognition of their achievements. The thresholds for graduation are slightly higher than those for inclusion. In order to be eligible for graduation, a country:

- Must satisfy thresholds in two of the three criteria in two consecutive triennial reviews

OR

- Must exceed the threshold in gross national income (GNI) per capita in two consecutive triennial reviews (i.e. US$2,460 in the 2018 triennial review). Furthermore, in this income-only criterion, the likelihood that the level of GNI per capita is sustainable must be deemed to be high.

After a country has become eligible for graduation for the first time, an ex ante impact assessment and a vulnerability profile by the United Nations Department of Economic and Social Affairs (UN DESA) and the United Nations Conference on Trade and Development (UNCTAD) are produced and delivered to the UNCDP for its deliberation at the next triennial review. When a country meets the graduation criteria in two consecutive triennial reviews, the UNCDP may recommend it for graduation. These recommendations are not exclusively based on the criteria scores – complementary country-specific information and the views of the Government of the country are also taken into account. UNCDP's recommendation of graduation is then submitted for ECOSOC's endorsement, and finally submitted for final decision by the General Assembly of the United Nations.[10]

Box 2. Criteria for the identification and graduation of least developed countries

The identification of least developed countries is currently based on three criteria: GNI per capita, human assets and economic vulnerability to external shocks. The latter two are measured by two indices of structural impediments, namely the HAI and the EVI.

- *Income criterion*, based on a three-year average estimate of GNI per capita in United States dollars, using conversion factors based on the World Bank Atlas methodology (under US$1,018 for inclusion, above US$1,222 for graduation, as applied in the 2021 triennial review)
- *HAI*, based on the following indicators: nutrition (percentage of population undernourished); health (mortality rate for children aged 5 years and under); education (the gross secondary school enrolment ratio); and adult literacy rate
- *EVI*, based on the following indicators: population size; remoteness; merchandise export concentration; share of agriculture, forestry and fisheries; share of population in low-elevated coastal zones; instability of exports of goods and services; victims of natural disasters; and instability of agricultural production

Source: United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States (UN-OHRLLS), "Least developed countries category", no date. Available at https://www.un.org/ohrlls/content/ldc-category (accessed on 16 December 2021).

10 UN-OHRLLS, *A Guide to Least Developed Country Graduation* (2019). Available at https://www.un.org/ohrlls/sites/www.un.org.ohrlls/files/un_graduation_booklet_2019_final_s.pdf.

The most recent graduation from least developed country status, that of Vanuatu, took place on 4 December 2020. Vanuatu, like other least developed and low-income countries, struggles with maintaining sustainable development, and graduated from the least developed countries list despite major setbacks due to climate change, natural disasters and the COVID-19 pandemic. As with other countries that have graduated, Vanuatu's success is partly the result of international aid that supported the country's stable economic growth, alongside success in its strong agriculture sector with increased diversification in agricultural crops and stocks.[11] Currently, 7 least developed countries are scheduled for graduation, while 9 are in different stages of the graduation process (see Table 1), leaving 30 least developed countries to work on their path to graduation.

While the IPoA focuses on least developed countries, related development programmes, including the Vienna Programme of Action (VPoA) for landlocked countries and the Small Island Developing States Accelerated Modalities of Action pathway, outline the international community's vision and strategy for their sustainable development. One specific aim of the IPoA was to enable half of the least developed countries to meet the criteria for graduation. Three countries graduated during the implementation of the IPoA in its decade of action (2011–2020): Vanuatu (2020), Equatorial Guinea (2017) and Samoa (2014). This is the same number as in the preceding two decades, when Maldives (2011), Cape Verde (2007) and Botswana (1994) achieved graduation (see Table 1).

Table 1. List of least developed countries by graduation status

Group	Countries (with scheduled graduation date, where applicable)	Criteria met
Countries scheduled for graduation	Bhutan (13 December 2023)	Income only
	Angola (12 February 2024)	Income only, GNI per capita, HAI, EVI
	Sao Tome and Principe (13 December 2024)	GNI per capita, HAI, EVI
	Solomon Islands (13 December 2024)	
	Nepal (2026)	
	Bangladesh (2026)	
	Lao People's Democratic Republic (2026)	
Countries recommended for graduation	Kiribati	Income only, GNI per capita, HAI
	Tuvalu	Income only, GNI per capita, HAI
Countries meeting criteria for two consecutive times	Myanmar	
	Timor-Leste	
Countries meeting the eligibility criteria for the first time	Cambodia	GNI per capita, HAI
	The Comoros	GNI per capita, HAI
	Djibouti	Income only
	Senegal	GNI per capita, HAI
	Zambia	GNI per capita, HAI

11 Zahlea Martin, "Least developed countries list: Vanuatu's graduation", Borgen Project, 23 February 2021. Available at https://borgenproject.org/vanuatus-graduation/ (accessed on 11 December 2021).

Group	Countries (with scheduled graduation date, where applicable)		
Remaining least developed countries (30 countries)	Afghanistan	Guinea	Niger
	Benin	Guinea-Bissau	Rwanda
	Burkina Faso	Haiti	Sierra Leone
	Burundi	Lesotho	Somalia
	Central African Republic	Liberia	South Sudan
	Chad	Madagascar	Sudan
	Democratic Republic of the Congo	Malawi	Togo
	Eritrea	Mali	Uganda
	Ethiopia	Mauritania	United Republic of Tanzania
	The Gambia	Mozambique	Yemen
Graduated least developed countries	Vanuatu (2020)	Samoa (2014)	Cape Verde (2007)
	Equatorial Guinea (2017)	Maldives (2011)	Botswana (1994)

Source: Department of Economic and Social Affairs, *The Least Developed Country Category: 2021 Country Snapshots* (2021).

While many least developed countries, prior to the onset of the COVID-19 pandemic in early 2020, accelerated their path to graduation, with some of them episodically meeting one or two graduation criteria (for example Lesotho, Togo and Zambia in 2018), 30 least developed countries have yet to meet any graduation threshold.[12] Poverty levels have decreased, on average for all least developed countries, by just five percentage points since 2011, and could bounce back after COVID-19. Another goal of the IPoA was a sustained economic growth at 7 per cent per annum. While positive, but not uniform, growth trends were observed in most least developed countries, this goal was not achieved. GDP growth in least developed countries was mainly negative in 2021, with an average of -0.556 per cent recorded, and double-digit negative GDP growth rates recorded in Lesotho (-11.1) South Sudan (-10.8) and Myanmar (-10.0). This is the lowest level of growth across the least developed countries since 1981, and down from a high of 8.221 per cent in 2007 and 4.339 in 2019. The sharp decline in 2020 can be attributed to the global decline in average GDP growth due to the COVID-19 pandemic, which places a further strain on least developed countries seeking to graduate.

The challenges facing least developed countries in achieving the SDGs, targets and indicators, the criteria for graduating from the least developed countries category, and IPoA goals, targets and actions, are numerous and require comprehensive approaches to address development issues on multiple fronts.

In the midst of one of the largest health crises in modern history, the global relevance of STI has been made abundantly clear, allowing us in a very short time to better understand the nature of the disease, its transmission and the development of vaccines to combat its spread.

STI in least developed countries, as they recover from the impact of the COVID-19 pandemic alongside developed nations, is more important than ever before, to help in overcoming the structural impediments to development and to achieve this sustainably – a requirement that developed nations in the global North did not have to fulfil on their path to development during the Industrial Revolution. Understanding why STI is relevant in least developed countries is further elaborated in the next chapter, setting the stage for chapter 3 that explores the key challenges and opportunities in STI development in least developed countries.

12 UN-OHRLLS, *Lessons Learned: Implementing the Istanbul Programme of Action for Least Developed Countries for the Decade 2011–2020—Preliminary Report* (2020), p. 2.

2. Science, technology and innovation in the least developed countries: more relevant than ever?

Long-term structural development challenges in the agriculture, education, energy, and health-care sectors, and more recent systemic pressures including climate change and the COVID-19 pandemic, contribute to the fragility of the least developed countries. The current health crisis has shown the potential for harnessing STI to assist in developing vaccines, treatments, and diagnostics to mitigate and deal with the COVID-19 pandemic. STI can also assist in addressing the other development challenges in least developed countries.

2.1 Structural development challenges in least developed countries

Least developed countries are faced with many challenges that constrain growth and development in various sectors, and greatly affect their overall effectiveness in meeting their targets in the 2030 Agenda for Sustainable Development. These challenges have been exacerbated with the further pressures of climate change and the COVID-19 pandemic. There is much potential in harnessing the power of STI for addressing development challenges, and many least developed countries have already demonstrated as such. However, the least developed countries face an additional constraint, as their development paths cannot follow those of developed countries, which have generated many negative externalities such as pollution, acceleration of climate change and depletion of natural resources.

Many factors have contributed to the underdevelopment of the least developed countries, including low levels of human capital development; poverty and high levels of unemployment; a lack of access to basic infrastructure (e.g. electricity, transportation and Internet connectivity) and basic services (water, health and social security); lack of productive capacity and ability to harness the means of production; dependence on natural resource exploitation and tourism; and weak governance, institutional capacity and private sector engagement. Methods and technologies for development are often imported from other contexts, and adapting them to local needs is an essential part of sustainable development in the least developed countries, particularly in sectors such as agriculture, education, energy, and health.

Structural challenges in the agricultural sector

Food insecurity is prevalent in least developed countries. Improvements in food production are necessary, as many children lack the necessary micronutrients for their development and well-being, with a proportion of stunted children as high as 31.2 per cent in 2019 across least developed countries. The limited access to technology, expertise and adequate infrastructure in these countries also often results in massive food waste, with adverse consequences on farmers' livelihoods and overall food security. For instance, Rwanda records 164kg of food waste per capita per year in households, compared to 50kg in the Netherlands and 79kg in Canada.[13]

Structural challenges in the education sector

In terms of human development, diet and well-being are essential for children's development and to enhance their performance at school. At the same time, building skills and human capital is highly dependent on the education system. The gross secondary school enrolment rate is one of the indicators of the HAI used to identify and evaluate the least developed countries status. For 2019, the gross percentage school enrolment rate in secondary education in least developed countries was 44.7 per cent for girls and 48.4 for boys, increasing over the past decades from a very low base of 13.71 per cent in the 1970s.[14]

This measurement is closely linked to STI, as STI provide solutions for better quality of and access to education, which in turn generate the capacities needed in the labour markets of least developed countries. The COVID-19 pandemic has exacerbated existing inequalities and challenges in accessing education, with lockdown measures forcing schools to close in countries around the world. New ways to reach out virtually to students beyond schools have developed thanks to STI; however, the lack of broadband and digital infrastructure, and the costs of access, in least developed countries remain a barrier to development.

The burden is greater among women and girls in least developed countries. They already faced barriers to

13 United Nations Environment Programme (UNEP), *Food Waste Index Report 2021* (Nairobi, 2021).
14 World Bank, "School enrollment, secondary (% gross)—least developed countries: UN classification", UNESCO Institute for Statistics. Available at https://data.worldbank.org/indicator/SE.SEC.ENRR?locations=XLThe (accessed on 12 December 2021).

accessing education prior to the pandemic, where due to long distances of travel and the cost of accessing education, the preference is often to send boys to school. Women and girls also assist in the household and are caregivers within their families and communities in least developed countries. This need for caregiving increased during the pandemic, which disproportionately impacted the elderly and further compromised girls' access to education.

Structural challenges in the energy sector

While there is a clear correlation between access to energy and most development indicators, 62 per cent of people in the least developed countries did not have access to electricity in 2017, a number which increases to as high as 80 per cent in rural areas.[15] Recent calculations show that more than half of citizens in least developed countries lack access to electricity.[16] An increase in electric generation by a factor of 3.4–6.8 would be required to increase the productive capacity necessary for development in the least developed countries.[17] Building complementary skills and technology capabilities, promoting access to green technologies, and fostering innovation that is conducive to both structural development and the transition to a green economy, are all necessary in the least developed countries.

The top performers in this sector are Afghanistan, Bhutan, Lao People's Democratic Republic, Nepal and Tuvalu, which have an electrification rate of greater than 75 per cent. Low and very low electrification rates are found in most of the African least developed countries, except for The Gambia, Senegal and Sao Tome and Principe, which have electrification rates above 50 per cent. Some least developed countries already benefit from electricity production from hydropower, which constitutes over 90 per cent of the electricity supply of Bhutan, the Democratic Republic of Congo, Ethiopia, Lesotho, Lao People's Democratic Republic, Malawi, Mozambique, Nepal and Zambia.[18] Solar generation has increased significantly, and total solar generation in least developed countries rose from 6GWh in 2000 to 446GWh in 2014, with solar home systems in Bangladesh accounting for almost half that country's gross electricity production. Wind power generation has seen a strong increase in Ethiopia. The Adama I (51MW) and Adama II (153MW) wind farms in Ethiopia represent a significant investment (over US$340 million) in the development of renewable energy by the Ethiopian Government, in a joint venture with a state-owned Chinese enterprise.[19]

Structural challenges in the health-care sector

A vast majority of the least developed countries are unable to provide basic health care to the public. The World Health Organization (WHO) estimates that 22 least developed countries must build their health-care systems from the very foundations.[20] There are 6 hospital beds for every 100,000 people in the least developed countries, compared to 52 in developed countries. Similarly, there are 3 medical doctors per 10,000 people in the least developed countries compared to 31 in developed countries. Many citizens cannot access health care, either due to high costs of treatment, or to a long distance to the nearest health-care centre. The existent health-care facilities are often without electricity, medicines, equipment or qualified personnel.

The role of STI in addressing these development challenges

STI can provide indigenous solutions and address these development gaps. The least developed countries have the potential to make incremental changes to showcase the ingenuity of countries doing more with less, and, with the requisite investment in STI, they can be supported on their path to graduation. This investment in STI in least developed countries will assist them in developing human resources to build their science systems, and enable them to create, adopt and absorb relevant technologies. There are already many examples of what STI have helped achieve in least developed countries, including the following:

- In the health sector, digitization and data platforms have enhanced patient care provision. For instance, in Bangladesh a Health Identifier Code has been

15 UNCTAD, *The Least Developed Countries Report 2017* (2017).
16 UNCTAD, "Over half of the people in least developed countries lack access to electricity", 1 July 2021. Available at https://unctad.org/topic/least-developed-countries/chart-july-2021 (accessed on 12 December 2021).
17 UNCTAD, *The Least Developed Countries Report 2017: Transformational Energy Access* (New York and Geneva, United Nations publication, 2017).
18 Ibid.
19 Grace Goodrich, "Top 10: wind farms in Africa", Energy Capital & Power, 22 June 2021. Available at https://energycapitalpower.com/top-10-wind-farms-in-africa/ (accessed on 12 December 2021).
20 WHO, "Building health systems resilience for universal health coverage and health security during the COVID-19 pandemic and beyond", WHO position paper, 19 October 2021.

provided to every citizen since 2013, and the Intelligent Dengue Tracking and Management System has also been developed.[21]

- In agriculture, Cambodia has developed "net houses" that allow farmers to cultivate the land within the structure as they would normally, but with protection from insects. In "packing houses", farmers can wash, prepare and pack produce for market, and store it in a cool room utilizing a "CoolBot" that tricks an air conditioner into supplying lower temperatures at a lower cost than refrigeration, extending the shelf life of products.[22]

- Early warning systems that use solar-powered and mobile data can enable the detection of changing weather and environmental conditions. For instance, in Cambodia, a water gauge system allows the detection of rising water levels, and provides voice-based alerts, suitable even for populations with low literacy levels, to locals via mobile phones.

2.2 More recent systemic pressures on least developed countries

Climate change

Climate change has already hit the least developed countries hard because of their current low adaptive capacity. Food security is significantly impacted, with frequent natural disasters putting already fragile agricultural systems under significant additional stress. Human habitat and biodiversity equilibrium are also threatened by an increase in the phenomena of extreme weather conditions such as typhoons, heatwaves and droughts.

Ministers from least developed countries requested that the goals of the twenty-sixth meeting of the United Nations Climate Change Conference of the Parties (COP26) reflect the acute needs of least developed countries in financing adaptation to climate change.

Photo credit: YODA Adaman on Unsplash

21 These examples are drawn from Bangladesh, Ministry of Planning, *Bangladesh Voluntary National Reviews (VNR) 2020* (Dhaka, General Economics Division, Bangladesh Planning Commission, 2020).
22 Ann Filmer, "Agricultural innovations help Cambodian farmers thrive", UC Davis, 8 October 2019. Available at https://www.plantsciences.ucdavis.edu/news/agricultural-innovations-help-cambodian-farmers-thrive (accessed on 6 December 2021).

Developed countries have made progress towards the commitment to deliver US$100 billion in climate finance to developing countries annually from 2020 to 2025. They are expected to meet this goal by 2023 at the latest. Over US$600 million was pledged to the Least Developed Countries Fund. Also, the United Kingdom of Great Britain and Northern Ireland, alongside Fiji, initiated the Taskforce on Access to Climate Finance, which will run trials with five pioneer countries (including three least developed countries) – Bangladesh, Fiji, Jamaica, Rwanda and Uganda – to support faster, easier access to climate finance for developing countries. The United Kingdom of Great Britain and Northern Ireland committed £100 million to support implementation of the taskforce's approach.

The national climate action plans that outline countries' nationally determined contributions to achieving targets set by the Paris Agreement, and their post-2020 climate-related actions, when aligned with STI, provide the least developed countries with long-term strategies towards becoming climate neutral by 2050. Both adaptation and mitigation technologies, notably those supporting the proper monitoring of natural events using robotics and big data, are key to ensuring economic competitiveness as well as environmental protection. The transition to a green economy, thanks to STI, guides global policymakers on challenges such as developing renewable energy and enhancing a more circular economy. For instance, the African-owned and led Africa Renewable Energy Initiative is technology-focused and looks to support the uptake of renewable energy, such as hydroelectric, solar and wind technology, and foster the transformative impact of their use.[23] Renewable energy can transform the economy, shifting away from the reliance on fossil fuels and potentially giving rural populations access to a more sustainable form of power, which will be an important driver for development.

COVID-19 pandemic

The outbreak of COVID-19 is another systemic burden on the least developed countries. While the effects of the pandemic are visible in many fields, a few key aspects regarding health, the economy, the role of digital solutions, and inequality will be addressed in this section.

The pandemic's impact on health in the least developed countries has been relatively low compared to in developed nations. Approximately 1,629 per million inhabitants were officially directly affected by the virus in least developed countries, compared with 52,271 per million in developed countries.[24] Recent developments, such as the uneven deployment of vaccines and the emergence of new variants of COVID-19, may however change the situation. Despite international initiatives such as COVAX, the slow vaccination rate in least developed countries may increase the probability of new variants deeply impacting and even developing within these countries, with all the related effects.[25]

On the economic front, the least developed countries have been profoundly affected. The pandemic abruptly interrupted a prolonged period of sustained growth for some least developed countries. A majority of the least developed countries have experienced economic contraction.[26] All least developed countries have been greatly impacted by the drop in external demand, lower commodity prices, the necessity of lockdowns and the decline of (international) mobility. Impacts on economies include negative short-term economic growth, structural changes leading to a medium-term growth slowdown, a rise in inequality, and a strong negative impact on employment and labour income. Key points to emphasize include the following:

- Tourism is a key sector of the economy in 42 of the 46 least developed countries, and tourism receipts are as high as 19 per cent of GDP for Cambodia and 17 per cent for Sao Tome and Principe.[27] The tourism-based service industry in least developed countries was severely impacted by the global travel restrictions imposed to halt the spread of the COVID-19 pandemic.

- The graduating least developed countries with a high level of exports and those more fully integrated into global value chains, such as Bangladesh and Myanmar, were hit the hardest by the decreasing trends in trade.

- Sources of external finance, such as remittances and FDI, have declined. The drop in remittances worldwide is steeper than during the 2009 global

23 See http://www.arei.org.
24 UNCDP, *Comprehensive Study on the Impact of COVID-19 on the Least Developed Country Category* (2021).
25 Paul Adepoju, "As Africa experiences 'worst pandemic week', COVAX promises accelerated delivery of vaccines from September", *Health Policy Watch*, 8 July 2021. Available at https://healthpolicy-watch.news/as-africa-experienced-worst-pandemic-week/ (accessed on 12 December 2021).
26 UNCDP, *Comprehensive Study on the Impact of COVID-19 on the Least Developed Country Category* (2021).
27 UNCTAD, *Investment Trends Monitor*, No. 36 (October 2020).

recession, down -7.2 per cent in 2020 and -7.5 per cent in 2021.

- It is expected that in the medium term, large enterprises will bounce back because they have sufficient cash reserves to absorb the impact on reduced business activity. However, micro, small and medium enterprises (MSMEs) and the informal sector are facing bankruptcy due to a lack of cash reserves, inadequate support measures from Government and limited access to credit lines.

- The crisis saw an aggravation of the external debt of least developed countries, with Zambia becoming the first least developed country to default due to the crisis and Angola reaching a debt of 123 per cent of its GDP. However, the initial situation varied greatly among the least developed countries, with GDP to debt ratio ranging from 9 per cent (Timor) to 141 per cent (Mozambique) in 2019.

The COVID-19 pandemic has also led to abrupt changes in work practices, educational methods and health systems. COVID-19 has accelerated the need for digital transformation in the least developed countries.[28] Digital technologies have provided very useful solutions during the crisis, but also increased the technological divide, as not all the populations of least developed countries have access to these solutions. A few key examples of solutions in the fields of health, education and finance include the following:

- STI have contributed solutions to institutions and the general public regarding the health crisis. Examples range from data intelligence platforms for identifying COVID-19 hotspots (in Bangladesh, Rwanda and Niger)[29] to vaccine registration apps (for example Surokkha in Bangladesh and KhmerVacc in Cambodia),[30] chatbots on social networks for disseminating information (in Niger and Mbaza in Rwanda)[31] and even drones for delivering vital medical supplies (Rwanda).[32]

- E-education online packages and radio broadcasts have provided novel perspectives for education and training.[33] For instance, telecommunications companies have launched online learning packages in Malawi and Nepal, and interactive radio broadcasts were deployed in Bangladesh, the Democratic Republic of the Congo, Ethiopia, Guinea, Lesotho, Madagascar, Malawi, Mali, Nepal, Nigeria, Somalia, Sudan, the United Republic of Tanzania, and Zambia.

- Digital finance and e-payment solutions have flourished as consumers were encouraged to use contactless payments, pushing least developed countries to accelerate capacity-building in Internet infrastructures and interoperability.[34] The use of mobile money for remittances has increased, exemplified by the deployment of electronic payment systems for issuing salaries to government staff in the Pacific Islands.[35]

As stated, due to increasing reliance on digital technologies during COVID-19, inequalities have further increased in terms of access to education and digital and financial inclusion, building on the unequal distribution of Internet and technology access prior to the COVID-19 crisis. This further emphasizes the importance of strengthening STI in the least developed countries. The next section considers how STI can be harnessed to ensure the sustainable development of least developed countries.

28 United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), *Strengthening the Resilience of Least Developed Countries in the Wake of the Coronavirus Disease Pandemic: Asia-Pacific Countries with Special Needs Development Report* (Bangkok, United Nations publication, 2021).

29 Sam Ajadi and Peter Drury, *Health Systems, Digital Health and COVID-19: Insights from Bangladesh, Myanmar, Pakistan, Benin, Nigeria and Rwanda* (2021); ITU News, "Interactive voice response: delivering life-saving information amid COVID-19 in Niger", International Telecommunication Union, 19 January 2021. Available at www.itu.int/en/myitu/News/2021/01/19/08/29/Interactive-Voice-Response-life-saving-information-COVID-19-Niger (accessed on 13 December 2021).

30 See www.surokkha.gov.bd; https://www.dataforcambodia.org.

31 United Nations Children's Fund (UNICEF), "Niger launches a chatbot on Whatsapp to answer COVID-19 queries", 5 May 2020. Available at www.unicef.org/niger/press-releases/niger-launches-chatbot-whatsapp-answer-covid-19-queries (accessed on 13 December 2021).

32 Harry Kretchmer, "How drones are helping to battle COVID-19 in Africa—and beyond", World Economic Forum, 2 September 2021. Available at https://www.weforum.org/agenda/2020/05/medical-delivery-drones-coronavirus-africa-us/ (accessed on 13 December 2021).

33 UN-OHRLLS, *State of the Least Developed Countries 2021: Building Back Better in Response to COVID-19* (2021), p. 78.

34 Ibid, p. 81.

35 UNCTAD, "Kiribati sets sights on overcoming hurdles to e-commerce", 20 May 2020. Available online at https://unctad.org/news/kiribati-sets-sights-overcoming-hurdles-e-commerce (accessed 13 December 2021).

2.3 The potential of STI for the sustainable development of least developed countries

The United Nations' *Research Roadmap for the COVID-19 Recovery* highlights the relevance of STI in the recovery globally, calling for "leveraging the power of science for a more equitable, resilient and sustainable future".[36] The Research Roadmap provides a broad framework for understanding how science can help societies achieve a quadruple bottom line for stimulating recovery, equity, resilience and sustainability, and enable them to obtain direct benefits from their COVID-19 recovery efforts. The knowledge base to guide effective action in this area currently lags behind what is needed to ensure that recovery efforts not only address challenges, but also harness the opportunities they present for the least developed countries. A global COVID-19 recovery programme presents opportunities to prioritize STI by harnessing science. The essential contribution of science strategies is recognized in their key role in improving data infrastructure, implementation science, development of rapid learning systems, knowledge mobilization and the science of science (see Box 3 for definitions).

Box 3. Five strategies to harness science for the COVID-19 recovery

Data infrastructure includes the organizations, policies, processes, systems and technologies involved in the collection, storage, management, oversight, distribution and use of data.

Implementation science is the study of methods and strategies to promote the uptake of effective interventions into practices, programmes and policies.

Rapid learning systems use the best available evidence and local data to inform decisions and commit to learn from their experiences as quickly as possible, to enable continuous improvements and to contribute to the global evidence base.

Knowledge mobilization refers to efforts designed to promote the use of research evidence to inform choices and generate positive impacts.

Science of science is focused on how research is funded, practised and evaluated, and how research cultures and systems can be made more efficient, open, inclusive and impactful.

Source: UN Research Roadmap for the COVID-19 Recovery: Leveraging the Power of Science for a More Equitable, Resilient and Sustainable Future, chapter 4: science strategies.

National priorities have evolved in a multilateral and regional framework of agreements targeted at the development of STI in least developed countries, or aiming at improving STI policies globally, including the following instruments:

- The IPoA, which outlines specific goals and priority areas for least developed countries in the decade 2011–2020, puts strong emphasis on the role development partners can play in transferring technologies and innovation with financial and technical support, as made clear in the report of the fourth United Nations Conference on the Least Developed Countries.[37]
- The VPoA provides another framework for the development of landlocked countries, including numerous least developed countries.[38] Top priorities of the VPoA include infrastructure development in energy, information and communication technologies.[39]
- Regional cooperation strategies on the African continent, home to most of the least developed countries, have also targeted STI as a means of

36 United Nations, *UN Research Roadmap for the COVID-19 Recovery: Leveraging the Power of Science for a More Equitable, Resilient and Sustainable Future* (2020).
37 United Nations, A/CONF.219/7.
38 Afghanistan, Burkina Faso, Burundi, Central African Republic, Ethiopia, Lao People's Democratic Republic, Lesotho, Malawi, Mali, Nepal, Niger, Rwanda, South Sudan, Uganda and Zambia.
39 UN-OHRLLS, *Vienna Programme of Action for Landlocked Developing Countries for the Decade 2014–2024* (2014).

boosting production capacities and development. The African Union's Agenda 2063 identifies STI and education as its second goal,[40] giving birth to the Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024).[41]

- Similar strategies and programmes have been developed in the Association of Southeast Asian Nations (ASEAN), such as the ASEAN Plan of Action on Science, Technology, and Innovation 2016–2025.[42]

- Pacific Islands States such as Kiribati, the Solomon Islands and Tuvalu are included in the Pacific-Europe Network for Science, Technology and Innovation, funded by the European Commission for the first two phases then continued independently.[43] This network furthers cooperation in STI development between Europe and islands of the Pacific Ocean. For these states, the Small Island Developing States Accelerated Modalities of Action pathway recognizes, as laid down in a resolution adopted by the General Assembly on 14 November 2014, that "science, technology and innovation are essential enablers and drivers for sustainable development".[44]

Tackling structural impediments to achieve the much-needed development in the least developed countries represent a challenge from the standpoint of STI policy because of interdependencies. STI solutions have been particularly relevant globally and the lack of strong STI systems in least developed countries has created an additional barrier for their development. Solutions to development challenges cannot be solely technological, and must also involve active measures to achieve poverty alleviation, reduce inequalities, develop basic infrastructure and improve universal access to health.

This highlights a tension between the need for development to catch up with developed countries, and the need for least developed countries to do this sustainably given global commitments to reduce carbon emissions, a constraint that developed countries did not consider during their development. This tension in Africa, where most of the least developed countries are located, shows that while African countries are making good progress in meeting climate change targets, they are slower in meeting development targets. The State of the Climate in Africa 2019 report provides a snapshot of current and future climate trends and associated impacts on the economy and sensitive sectors such as agriculture, and highlights lessons for climate action in Africa, including identifying pathways for addressing critical gaps and challenges.[45] The report notes that in leveraging the transition towards climate resilient economies and growth, Africa has made great strides. Over 90 per cent of African countries have ratified the Paris Agreement,[46] and many African nations have committed to transitioning to green energy within a relatively short time frame, with clean energy and agriculture being prioritized in over 70 per cent of African countries' national determined contributions to the Paris Agreement. While the economic development priorities of the continent should be seen in the context of the need for global climate action and transitioning to a green economy, the African Climate Policy Centre cautions that Africa is disproportionately vulnerable to climate change due to its very low socioeconomic base.[47]

The least developed countries currently experience a high level of fragility because of a myriad of challenges that constrain their development. The relevance of STI in addressing these challenges has been recognized by global and local communities. The work of building and strengthening the STI systems and national innovation systems of the least developed countries requires continued commitment and investment, including in the next decadal plan for the least developed countries.

> **The COVID-19 pandemic has shown what can be achieved in a short amount of time when global and local communities work together to harness the power of science.**

Similarly, science can help improve the understanding of the development challenges in least developed countries, and in developing and adapting technologies and harnessing innovation to mitigate and confront fragility resulting from a lack of development.

40 African Union, "Goals & priority areas of Agenda 2063", no date. Available at https://au.int/agenda2063/goals (accessed 14 December 2021).
41 African Union, *Science, Technology and Innovation Strategy for Africa 2024* (2014).
42 ASEAN Secretariat, *Plan of Action on Science, Technology and Innovation 2016–2025* (Jakarta, 2017).
43 See https://pacenet.plus/.
44 United Nations, A/RES/69/15.
45 World Meteorological Organization, *The State of the Climate in Africa 2019* (Geneva, 2020).
46 The Paris Agreement sets out a global framework to avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C. It also aims to strengthen countries' ability to deal with the impacts of climate change and support them in their efforts.
47 World Meteorological Organization, *The State of the Climate in Africa 2019* (Geneva, 2020).

3. Main insights on the state of STI development in the least developed countries

The STI performance of least developed countries is lower than the world average, but there is substantial internal variation that can yield insights into the performance and opportunities for these emerging science systems. While the science system across the least developed countries is characterized by a low government expenditure on R&D, there is a resilience and creativity of scientists working within these frugal science systems. The least developed countries, particularly those in the process of graduation, have also seen a significant growth in scientific publications and citations over the past two decades. With regards to technology, the least developed countries remain unequally prepared to seize the opportunities of digitization and the Fourth Industrial Revolution, because they typically lack sufficient access to reliable infrastructure, such as access to electricity and the Internet, particularly high-speed and reliable Internet. If addressed, the opportunities offered by the Fourth Industrial Revolution can result in fast improvements through leapfrogging to new technologies. Concerning innovation, firms in least developed countries are highly engaged with various forms of R&D and innovation, but the degree of formalization and novelty of these innovations (measured using patents as a proxy) remains relatively low.

STI in least developed countries tend to focus on global challenges and display unique features such as indigenous knowledge and culture, citizen engagement and grass-roots innovations which should be recognized. The evolving policy landscape in least developed countries shows rising awareness on the importance of STI and the governance of STI systems, which has been further revealed during the COVID-19 crisis. The business case for investment in STI is clear, as STI build human capital and absorptive capacities, and yield economic benefits.

This chapter presents the main empirical and analytical insights generated through the high-level study on the state of STI in the least developed countries. The insights have been bundled in seven short sections as follows. Sections 3.1, 3.2 and 3.3 describe the state of the STI systems in brief, considering system inputs, throughputs and outputs. Throughout, the comparative lenses of the graduation levels for least developed countries and global averages are used to consider the relation between development levels and STI performance. Section 3.4 complements this with a deeper assessment of how STI systems in least developed countries relate to the SDGs, whereas section 3.5 focuses on specific features that are typical for least developed countries in relation to their STI systems, such as the role of diaspora and specific types of innovation such as frugal and grass-roots innovation. Section 3.6 describes the current state of governance and policy arrangements on STI in the least developed countries, and 3.7 considers the impact of COVID-19 on STI systems. Finally, section 3.8 presents the business case for STI in least developed countries.

STI development in the least developed countries differentiates between the domains of science (the basic pursuit of knowledge about the natural and social world), technology (the practical application of this knowledge to solve real world problems through developing and applying new technologies) and innovation (the diverse ways how new goods and services are produced based on new technologies or business/organizational models). While these are distinct domains, there is a strong relationship between them that contributes to STI development in the least developed countries.

The subsequent sections are based on the insights of qualitative research (including a literature review, policy interviews and country case studies) as well as quantitative data (existing and novel indicators). The headline indicators for this report – science, technology and innovation – are based on existing quantitative data on the main trends and perspectives on STI in least developed countries, using sources where data were systematically collected over regular time periods, according to agreed data standards and centrally coordinated to ensure consistent quality. It must be noted, however, that while all efforts were made to source data that were systematically collected, there were still instances in which data were not available consistently for all countries and time periods. Figures in the tables are therefore based on averages for the 2000–2020 period. Using data from existing sources and for countries and time periods for which data were available, the key features and trends are discussed below.

3.1 Frugal science systems: underfunded yet buoyant

Table 2 highlights the scientific performance of the least developed countries by graduation status across various categories, also compared against the world average. Least developed countries have a lower absolute performance compared to the world average, but there is substantial internal variation that can yield insights into the performance and opportunities for these emerging science systems. In this section, the input, throughput and output performance of the science systems will be discussed, after which a short reflection on possible implications is presented.

Table 2. Main insights on the state of science in the least developed countries.[48] Figures are based on averages for the 2000–2020 period.

	Enrolment in tertiary education per million capita	PhD students per million capita	R&D personnel per million capita	% female R&D personnel	Scientific publications per million capita	Scientific citations per million capita	Government expenditure on R&D [GERD] (%)
Average, all countries	26,995	797	3,723	37%	562	12,292	0.93%
LDCs (mean)	5,797	45	224	36%	23	432	0.21%
Average, LDCs meeting criteria for first time	6,607	123	475	23%	22	347	0.18%
Average, LDCs meeting criteria 2 consecutive times	12,999	6	63	72%	9	89	0.09%
Average, LDCs recommended for graduation	-	-	-	-	140	2,442	-
Average, LDCs scheduled for graduation between 2023 and 2026	8,441	11	568	17%	34	544	0.14%
Average, remaining LDCs	5,027	40	187	36%	15	331	0.22%

Source: Various sources, including United Nations Educational, Scientific and Cultural Organization (UNESCO) and SCImago.

Inputs: limited funding

In terms of input indicators, the science systems in the least developed countries are characterized by relatively low aggregate government expenditure on R&D (government expenditure on research and development [GERD]; see Table 2). While the world average of aggregate spending is around 0.93 per cent of GDP, the most recent average across least developed countries is only 0.21 per cent, with a substantial share of least developed countries not reporting recent data. This is far from most Governments' targets, and from the African Union target of 1 per cent. When excluding more applied and innovation-oriented expenditure, which is typically the majority of R&D, direct government investments in pure science can be characterized as extremely limited in many least developed countries.

The data and case studies show that countries closer to graduation invest more in R&D, including "pure science": development levels and investment in science show a strong degree of correlation. Benin and Malawi, for instance, have indicated that weak funding systems have led to insufficient infrastructure in their countries, such as substandard laboratories, and insufficient human capacity to perform science. In the Democratic Republic of the Congo, GERD in 2015 was 0.41 per cent, compared to a target set at 1 per cent by the African Union. Despite this picture, there are examples of some progress in

48 Data on STI in LDCs are characterized by a high degree of incompleteness in terms of availability across all countries and years. This and subsequent tables are based on the available information, and may not reflect the situation across all LDCs. More information on the methodology is available in Appendix 4.

the ratio of research expenditure in least developed countries, as will be seen.

The generally low level of spending on R&D can be explained by an overall low share of public spending in least developed countries, a quite nascent competitive funding system for STI (essentially in the form of grants) and the risk-averse culture within the public sector which seeks rapid results and is reluctant to pursue anything that might lead to a temporary failure. For instance, Benin and the Democratic Republic of the Congo highlight the existence of binding disbursement procedures for public funds as a barrier to accessing funds. This low government spending is insufficiently counterbalanced by private funding, which remains inadequately incentivized by fiscal instruments and a bank sector which is averse to investing in innovative firms. There is also an overreliance on development partners when it comes to funding research and innovation activities.

Throughput: a divergent view

On throughput indicators (see Figure 3), in particular enrolment in higher education and the number of PhD students, we see a similar positive correlation between graduation levels and throughput performance, albeit with more internal variation. Regarding the number of PhD students, the average for the least developed countries meeting the criteria for graduation for the first time is 123 per million capita, significantly higher than the average for all least developed countries at 45 per million capita, and the average of those remaining least developed countries at 40 per million capita.

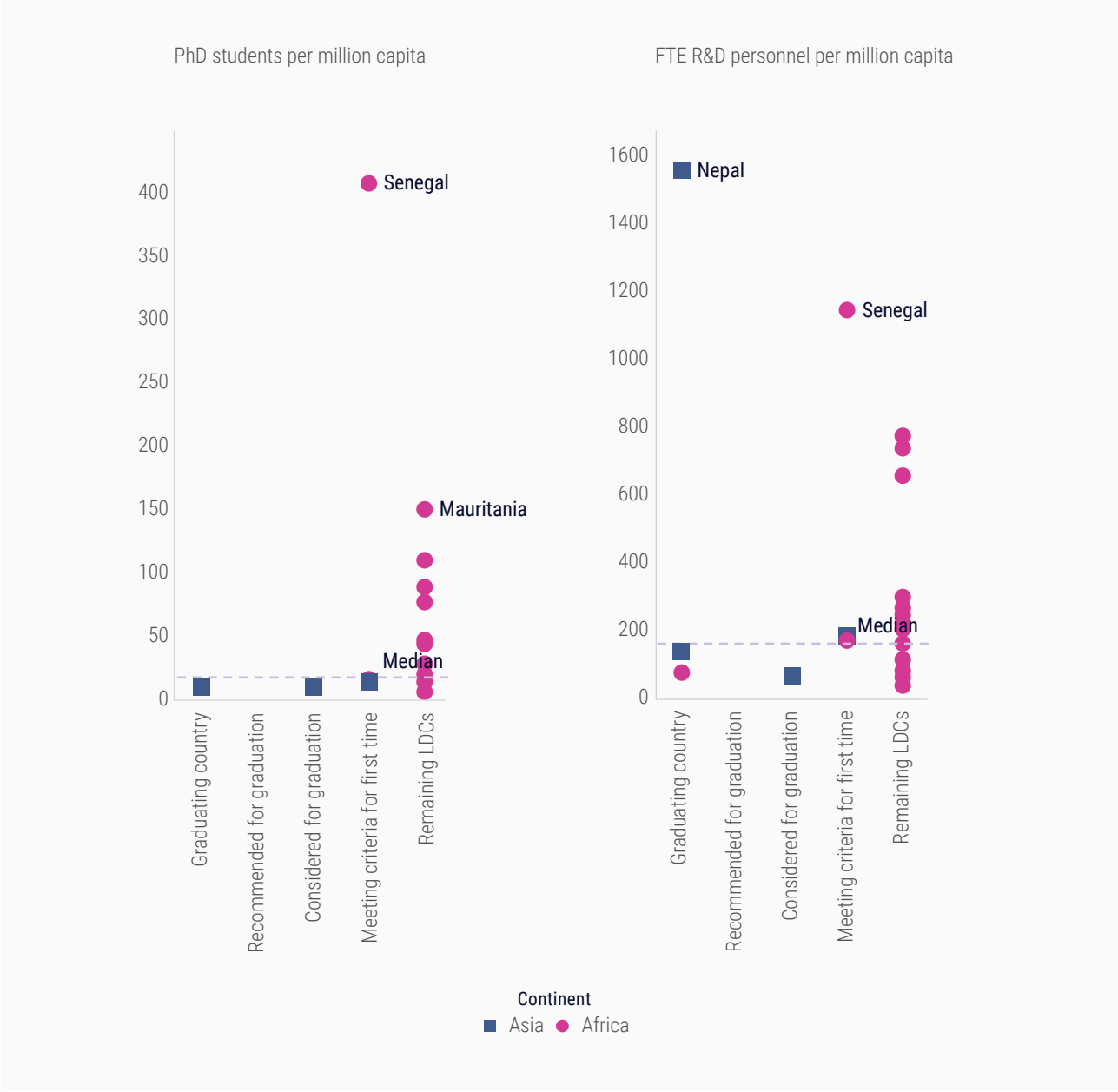
However, this pattern disappears within different graduation levels themselves, which display much greater country-level variation. For instance, Senegal (which has met the eligibility criteria for the first time) is the best-performing country in Africa, with 407 PhD students per million capita in 2015; all other African countries are in the low double-digit numbers.[49] For overall tertiary enrolment, a pattern is visible that the throughput performance increases with development levels: only remaining least developed countries score lower than the average.

Similar country-level variation can be seen for R&D personnel, where the average for least developed countries meeting criteria for graduation for two consecutive times is much lower at 63 per million capita, whereas the number for the remaining least developed countries is 187 per million capita; both are lower than the average for all least developed countries at 224 per million capita, with the least developed countries scheduled for graduation much higher at 568 per million capita, and those meeting the criteria for the first time at 475 per million capita. The two best-performing countries are either scheduled for graduation (Nepal) or meeting the graduation criteria for the first time (Senegal), which indicates that investment in science has positive development outcomes.

Photo credit: Kojo Kwarteng on Unsplash

49 Senegal has a history of strong university education, in particular at Cheikh Anta Diop University, and serves as a regional centre of excellence in that regard.

Figure 3. Strip plot of science throughput indicators for the least developed countries



Source: UNESCO and SCImago. Note: data points are based on last available data. For the full country data, see Appendix 3.

From the data available, current scientific capacity measured by number of R&D personnel per capita is low in the least developed countries, and this may be constraining their STI development. Most countries have fewer than 300 R&D personnel per million capita, with only Mauritania (734 per million capita), Sudan (767 per million capita), Senegal (1,139 per million capita) and Nepal (1,551 per million capita) performing better. With Nepal scheduled for graduation and Senegal meeting the eligibility criteria for the first time, investment in science appears to have positive development outcomes in least developed countries.

To address the lack of R&D personnel, there has been some progress in the ratio of research expenditure in least developed countries. For instance, in Bangladesh, the Government is planning to focus more on R&D as part of its Vision 2041, positioning the country as a knowledge economy. Vision 2041 is a national strategic plan to develop the socioeconomic standing of Bangladesh, issued by Prime Minister Sheikh Hasina; Bangladesh aims to achieve high-income status through industrialization by 2041. The Government plans to spend almost 80 per cent of the national R&D budget on specialized R&D centres, 15 per cent on corporate laboratories and 5 per cent on universities.

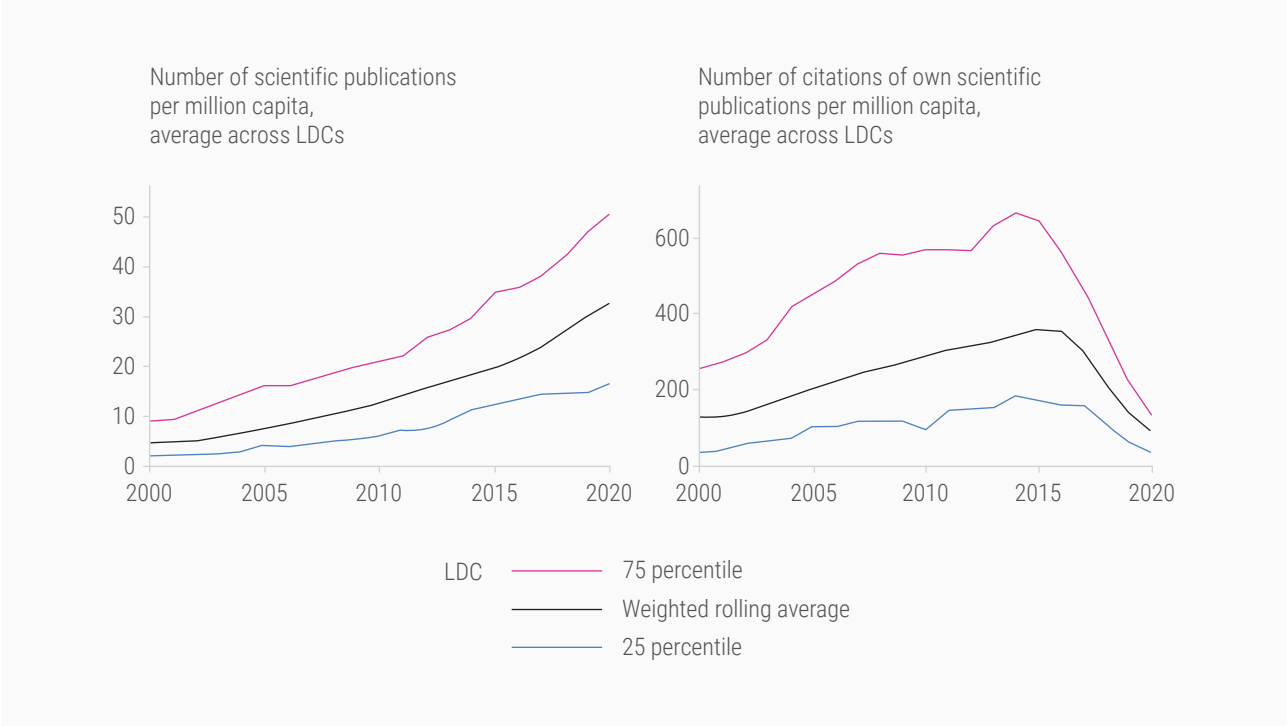
3.1.3 Output: rising performance from a low base

When focusing on science system outputs and knowledge production, here measured through publications and citations (a proxy for the quality of publications), the data in Figure 4 provide several clear insights.

Figure 4. Strip plot of science output indicators for the least developed countries

Source: UNESCO and SCImago. Note: data points are based on last available data. For the full country data, see Appendix 3.

Figure 5. Progress on science headline indicators in the least developed countries



Source: SCImago. Note: citations accumulate over time, therefore the decline in the last few years on the right graph is not likely to reflect a real decline as time progresses.

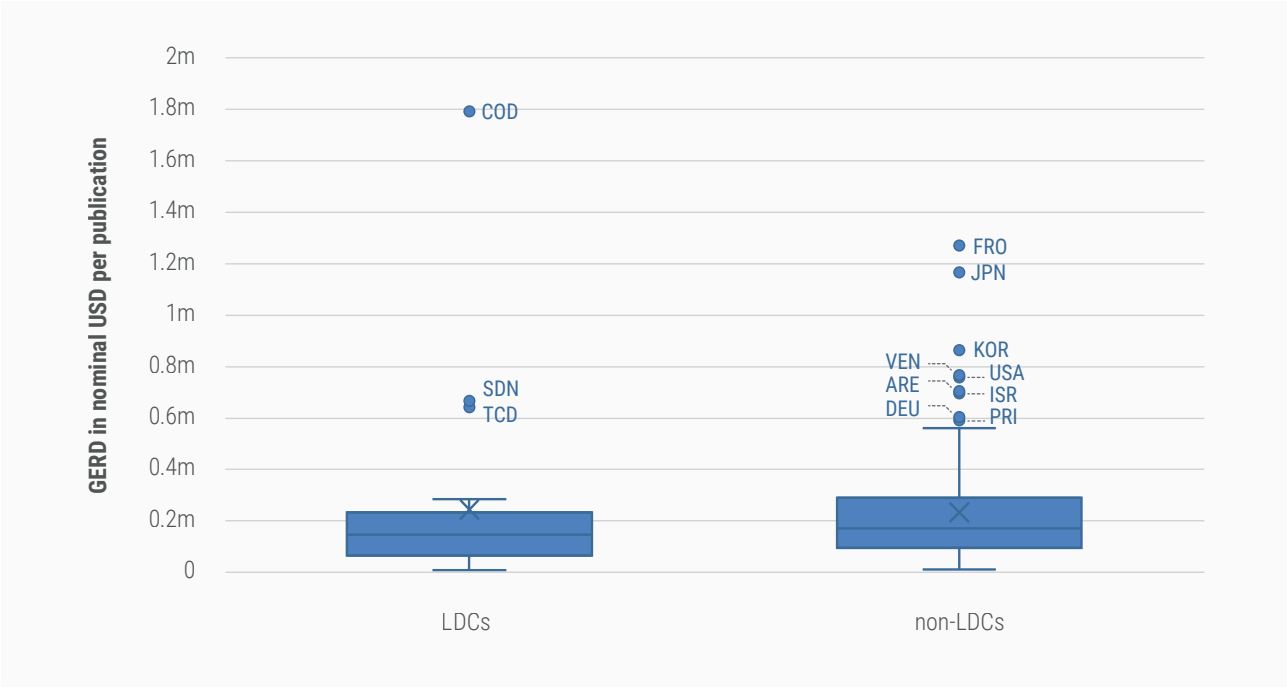
Starting from a low base, the least developed countries have seen considerable growth in scientific output, indicated by the number of publications in peer-reviewed journals from 2000 to 2020 (see Figure 5). This is faster than the growth rate observed in Organisation for Economic Co-operation and Development (OECD) countries. The decline in citations visible in the latter years is a result of citation accumulation over time, in which recent publications naturally have lower citation rates owing to the shorter timespan in which to receive citations. Yet despite this growth, the least developed countries lag behind the rest of the world in terms of number of publications. The number of publications per capita remains much lower than the levels observed in OECD countries, in which leading countries are achieving several thousand publications per million capita.

The increasing scientific production of countries graduating or scheduled for graduation indicates that investment in science can assist countries on their paths to graduation. Least developed countries recommended or scheduled for graduation perform better (respectively 140 and 34 publications per million capita) compared to the average for all least developed countries, 23 publications per million capita. The average number of citations for countries with these two classifications is also above average: least developed countries recommended for graduation in 2021 counted 2,442 citations per million capita; those scheduled for graduation, 544 citations per million capita; compared to an average of 432 citations per million capita for all least developed countries.

Bhutan, graduating in 2023, is the highest performing country, producing 280 publications and 128 citations per million capita in 2020. The two countries recommended for graduation perform well: Tuvalu with 254 publications and 85 citations per million capita, and Kiribati with 151 publications and 84 citations per million capita. Nepal, which is scheduled for graduation, also has a high number, at 99 publications and 126 citations per million capita, as does Solomon Islands, a country scheduled for graduation, which produced 95 publications and 50 citations per million capita.

Interestingly, if a measure of publication efficiency (Figure 6) is considered, least developed countries score relatively well compared to other countries in terms of total government investment in R&D. This is a rather imprecise measure, as GERD also includes more innovation-oriented investment. Nevertheless, it is an indication that least developed countries are – to some extent – able to leverage lower costs and frugal approaches to deliver scientific results with limited means. This is further discussed in the next subsection and section 3.7.

Figure 6. Gross expenditure on R&D in nominal US$ per publication



Outlook: frugal science systems

The above analysis can be summarized in several key insights. First, least developed countries exhibit very low government investments in science, with a large gap between current levels of expenditure and official policy targets, although countries closer to graduation typically already spend more. Second, there is significant variation in performance at the throughput levels, yet in terms of scientific output, performance is more correlated to graduation levels.

There are two likely explanations for this divergence. First, scientific output has a long output lag: investments in PhD students, for example, may only lead to a rise in publications (i.e. output) years later. Countries having recently begun investing in science will only see their outputs rise substantially in 5–10 years. Second, the divergence between throughput and performance can also highlight a productivity gap, of some science systems already being in a better position to produce strong scientific outputs. Factors may include governance and institutional quality (see section 3.9), a historical tradition of strong university and centres of excellence, and international ties to promote scientific collaboration (see section 3.5 on diaspora) and language, with a de facto penalty for non-English speakers in most international scientific publications.

Another striking finding from the qualitative insights and the data is the resilience and creativity of scientists operating in least developed countries. With often limited or – in some cases – no public support, scientists still manage to produce valuable knowledge for science and society. They do so by using creative tools and methodologies,[50] leveraging international networks and funders for supervision, and exhibiting great personal dedication and drive. On the other hand, some costs remain challenging, such as publication fees, as indicated in the interviews, although open science trends may offer an alternative in this regard in the future. While it is beyond discussion whether a funding gap exists in reaching public targets and developing a more robust and internationally competitive science system in least developed countries, this "frugal science" spirit provides an entrepreneurial basis that can be built upon when articulating the business case for science in least developed countries (see section 3.8).

3.2 Technological (r)evolution: the leapfrogging potential

Digitization can be a differentiating factor between more and less productive firms in least developed countries.[51] Digital goods, e-commerce and the service trade

50 Sara Reardon, "Frugal science gets DIY diagnostics to world's poorest", *New Scientist*, 4 September 2013. Available at https://www.newscientist.com/article/mg21929334-400-frugal-science-gets-diy-diagnostics-to-worlds-poorest/ (accessed on 14 December 2021).

51 OECD, *Productivity Growth in the Digital Age* (Paris, 2019).

provide a unique opportunity for MSMEs to take part in global trade and enhance their financial inclusion.[52] Opportunities lie especially in three critical sectors: agriculture (which employs 60 per cent of workers in least developed countries), manufacturing and digital financial services. In agriculture, digital platforms that provide smart logistics and distribution services can increase productivity and diversification.[53] In manufacturing, new technologies can improve product design, automate operations and improve supply chain management to lower production costs.[54] Digital financial services, such as mobile money and remittance payments, can facilitate all operations.

The state of technology is discussed in the sections below, borrowing from the statistical indicators in Table 3, in addition to interviews, surveys and a literature review.

Table 3. Main insights on the state of technology in the least developed countries. Figures are based on the 2000–2020 period.

	Proportion of population with access to electricity (%)	Proportion of population covered by at least a 2G network (%)	Fixed Internet broadband subscriptions (%)	Mobile money account (% age 15+)	Gender difference Mobile money account (% age 15+)	Email usage among firms (%)	Website usage among firms (%)	Technicians per million capita	Proportion of medium- and high-tech manufacturing value added (%)	High-tech exports minus reimports (% of manufactured trade)
Average, all countries	81%	89.2%	9.98%	24%	-1.2%	66.3%	42.2%	602	24.3%	10.1%
LDCs (mean)	36%	72%	0.35%	25.8%	5.5%	48.2%	23%	46	11.7%	5.7%
Average, LDCs meeting criteria for first time	48.8%	82.9%	0.46%	16.1%	1.8%	57.6%	31.8%	55	19.7%	3.1%
Average, LDCs meeting criteria 2 consecutive times	53.5%	77.1%	0.05%	42.7%	1%	36%	14%	19	10.6%	2.3%
Average, LDCs recommended for graduation	89.8%	39.5%	1.67%	-	-	-	-	-	-	6.6%
Average, LDCs scheduled for graduation between 2023 and 2026	56.4%	77.2%	0.78%	19.2%	6.0%	45.6%	23.3%	185	8.6%	10.8%
Average, remaining LDCs	24.5%	69.1%	0.13%	26.9%	4.7%	48.5%	22.3%	41	11.0%	5.2%

Source: Sustainable Energy for All, International Telecommunication Union (ITU), UNESCO and World Bank Enterprise Surveys.

52 United Nations Industrial Development Organization, "Technology as a driver of structural transformation in the LDCs", 3 August 2021. Available at https://www.unido.org/news/technology-driver-structural-transformation-ldcs (accessed on 15 December 2021).
53 Aarti Krishnan, Karishma Banga and Joseph Feyertag, "AG-Platforms in East Africa: national and regional policy gaps", ODI Agritech Series (Supporting Economic Transformation, 2020).
54 UNCTAD, *The Least Developed Countries Report 2020: Productive Capacities for the New Decade* (New York, United Nations publication, 2020).

Inputs to the technological catch-up: the promise of the digital transformation

The least developed countries remain unequally prepared to seize the opportunities of digitization and the Fourth Industrial Revolution. The use of data require Internet infrastructures that can support cloud computing and high volumes of dataflow. The least developed countries still lack appropriate infrastructures, including universal access to electricity and broadband Internet connections, which are critical for technological development (see Figure 7). Even though the spread of mobile phone coverage and use holds potential for least developed countries, the high cost of Internet access is recognized by national authorities as a major obstacle. A further concern is that although countries in sub-Saharan Africa have seen substantial increases in mobile broadband coverage since 2014, with over half a billion people living in areas with a mobile broadband network, they are not yet using mobile Internet.[55] Furthermore, significant gender and rural/urban gaps persist, with women 37 per cent less likely to use mobile Internet than men.

Figure 7. Strip plot of technology input indicators for the least developed countries

Source: ITU, UNESCO and World Bank.

55 Anne Delaporte and Kalvin Bahia, "Mobile Internet connectivity 2021: sub-Saharan Africa—key trends", GSM Association, September 2021. Available at https://www.gsma.com/r/wp-content/uploads/2021/09/The-State-of-Mobile-Internet-Connectivity-2021-Sub-Saharan-Africa.pdf (accessed on 15 December 2021).

Access to electricity is the minimum requirement for creating a context that allows for technological development, and one of the most pressing factors.

There is strong split between the least developed countries that have not yet met the graduation criteria, and the countries that have met the criteria at least once, as Figure 7 shows. Access to electricity is one of the most pressing factors that needs to be addressed for the countries that have not yet met any of the criteria. For the adoption of STI in the least developed countries, is it clear that access to electricity and broadband Internet are critical.

On average, 36 per cent of the population of least developed countries have access to electricity. The remaining least developed countries are the only category to have below-average access (24 per cent). In contrast, least developed countries recommended for graduation and those graduating have higher access than average (89.8 per cent and 56.4 per cent respectively). However, an increase in access is progressing across least developed countries.

In the field of mobile telecommunications, in the 2000s, Cambodia, The Gambia, Mali, Nepal and Timor-Leste had less than 3 fixed telephone subscriptions per 100 inhabitants, well below the global average of 23.1. By 2017, however, these countries had bypassed the development of landline infrastructure and reached levels of mobile subscriptions per 100 inhabitants that were above the global average of 108.9: The Gambia (139.2), Nepal (123.2), Timor-Leste (119.3), Cambodia (116) and Mali (112.4).[56] The rapid adoption of mobile technology has also contributed to innovative financial technology services. In Afghanistan, for instance, the "M-Paisa" initiative, a mobile phone-based money transfer, payments and microfinancing service, enables national remittances, salary disbursements, airtime purchases, bill payments and merchant services. According to the World Bank, the programme has a great potential for the economy of the country, as less than 3 per cent of the population is banked; however the fragility of the current political situation may hamper this progress.

The coverage of 2G mobile networks shows that most least developed countries are able to provide mobile network coverage for a large part of their populations. Globally, mobile network coverage is available to 89 per cent of people; for more than half of the least developed countries (24 out of 46), there is coverage of over 90 per cent. For the share of population covered by at least a 2G network, the upward trend has stabilized over the past 10 years, with an average of 72 per cent of the populations in least developed countries covered. Rural populations are less favoured, yet on average only 17 per cent have no coverage at all. Only three countries have coverage lower than 50 per cent, which are Tuvalu (recommended for graduation) and Somalia and South Sudan (remaining least developed countries). Somalia has the lowest coverage, at 47 per cent. Most countries in graduation (all categories except the remaining least developed countries) show coverage close to 80 per cent, except least developed countries recommended for graduation – Tuvalu and Kiribati – which face severe connectivity issues (39 per cent coverage), probably linked to being small islands. The remaining least developed countries are a little behind in terms of levels of coverage (average of 69 per cent).

Throughput: access to the Internet and industry-academia linkages

Globally, the Internet is used by 53 per cent of people.[57] In the least developed countries, although the average coverage is as high as 86 per cent in 2020, the average proportion of the population that uses the Internet is only 18 per cent (the median figure is 14 per cent). A factor that may influence Internet usage is affordability, with information and communications technology (ICT) services in least developed countries remaining prohibitively expensive.[58] Additionally, least developed countries have a low Internet user gender parity score (0.53), which has worsened since 2013 (0.70).[59] This is explained by low mobile phone ownership and gaps in the skills required to use digital technologies among women. Metrics on the usage of email and websites among firms in least developed countries show an average of 48 per cent of firms using email and 23 per cent of firms using websites. There is an upward trend in the share of firms using a website.

Data centres are a key part of ICT infrastructure, especially for the collection, storage and transmission of large volumes of data. While progress still needs to be made, as much of the current infrastructure in least developed countries is not localized, a notable step is the establishment of data centres across Africa.[60]

56 UNCTAD, "Leapfrogging: look before you leap", policy brief, No. 71, December 2018.
57 ITU, *Measuring Digital Development: Facts and Figures* 2019 (2019).
58 ITU, "The affordability of ICT services 2020", policy brief, February 2021.
59 ITU Development Sector, *Measuring Digital Development: Facts and Figures 2020* (2020), p. 8.
60 See https://www.africadatacentres.com/.

For example, Burkina Faso is opening a data centre so the Government can modernize its health information system and strengthen the sovereignty of the State in the management of health information. This holds equally true for data infrastructures in other sectors such as education, security and meteorology (including disaster warnings). The least developed countries are looking to develop their data capacities across all sectors.

To foster the use of data, regional cooperation to pool data, data centres and cloud-based archives on the model of the European data portal would tremendously increase access use,[61] but training on the use of data will also be necessary.

Engagement in the digital transition also presupposes having the capacities and skills for it. Skills deficits are still hindering development.[62] The human capital available for facilitating technological development can be measured by the number of technicians per capita; although the data are sparse for this indicator, least developed countries scheduled for graduation display four times more technicians per capita than least developed countries which have not entered the graduation process. Therefore companies, especially in least developed countries, and notably companies that were not born digital, must invest in skills and organizational changes, and eventually revise their business model. These changes all pose risks and imply costs, especially in the least developed countries where the ecosystem is characterized by small companies that tend to have limited capital investment capacity. It is relatively difficult for companies to acquire the right profiles in least developed countries, where limited digital training is available.

At a national level, academic–industry linkages are key for developing technologies. Based on the survey conducted, several least developed countries such as Burkina Faso and Burundi display and encourage technology transfer and collaboration between academics and industry. Evidence indicates that participation in European scientific programmes produces increased measures of R&D spillover, including production of patents. Resource pooling allows least developed countries to reinforce strategic collaboration and knowledge-sharing among various actors, such academia, research institutions, networks of centres of excellence, and the private sector, to create an effective ecosystem for capability development, technology transfer and commercialization. The survey shows that the private sector, including individuals, business entities, trade unions and community organizations, has not been sufficiently sensitized to effectively participate in STI development and in sponsoring research programmes, and points to the lack of collaboration between public authorities and civil society, as well as the absence of important pilot projects between Government and industry partners.

Outputs: Opportunities in reverse engineering and indigenous technologies

Least developed countries often have a weak technological foundation. Looking at technology outputs of these countries through the indicator of medium- and high-tech manufacturing value added, the least developed countries perform poorly overall (average of 11.7 per cent), compared to 24 per cent globally.

> **To catch up on this, key drivers are acquiring, mastering and adapting new products, technologies or managerial structures previously developed by the technology leader and, eventually, breaking into new markets, and expanding and consolidating participation in those markets.**

In the economic context of least developed countries, reverse engineering is an innovative solution that can enable them to catch up technologically. Developing a product by starting from the specific needs of the country allows considerable time and cost savings. This solution therefore allows the technological gap with more advanced economies to be reduced quickly and efficiently, while increasing competitiveness and gaining a share in global trade. The idea that technologies can be transferred from developed and industrialized countries to developing countries through economic activity has been at the centre of both policy and research circles. FDI and trade, particularly through the import of capital goods, constitute one of the main channels of international technology transfer.

Technologies can be transferred through direct or indirect channels. Direct channels involve explicit transactions from one party to another, such as the licencing of technologies or trade in goods. The fact that local firms in least developed countries buy foreign technology and import products from industrialized countries will enhance their capacity and productive processes.

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61 See https://data.europa.eu/en/about/about-dataeuropaeu.

62 Jan Fagerberg, Erika Kraemer-Mbula and Edward Lorenz, "An evolutionary analysis of transformative change in LDCs: the cases of Kenya and Rwanda", Working Papers on Innovation Studies, No. 20210623 (Oslo, Centre for Technology, Innovation and Culture, University of Oslo, 2021).

Indirect transfers consist of the indirect spillovers and externalities from the direct transfer, as well as the presence of and exposure to the foreign technology that can spread to the rest of the economy. For instance, FDI can contribute to a labour turnover effect, whereby workers who are trained in foreign firms bring their knowledge to domestic firms in least developed countries through employment, for instance in a multinational company with a branch located in a least developed country. This can lead to a demonstration effect, whereby domestic firms imitate and reverse engineer the products supplied by foreign companies. As evidence suggests, competition from imported goods can lead to a supply stimulus, giving MSMEs in least developed countries an opportunity to learn and imitate, as well as to adapt goods and services to local market conditions.[63]

> **However, the potential for reverse engineering in the least developed countries depends on the complexity and sophistication of the imported technology in relation to the sophistication of the local formal economy in the least developed country, as well as local entrepreneurs' skills and firms' absorptive capacity.**

Interesting examples include the ThirdEye project in Mozambique, which used low-cost drones to help small-scale farmers improve crop production by 41 per cent and reduce water use by 9 per cent. In Bangladesh, the Internet of things is being used to assess groundwater chemistry and protect people in the Ganges Delta from drinking water that is contaminated with arsenic.

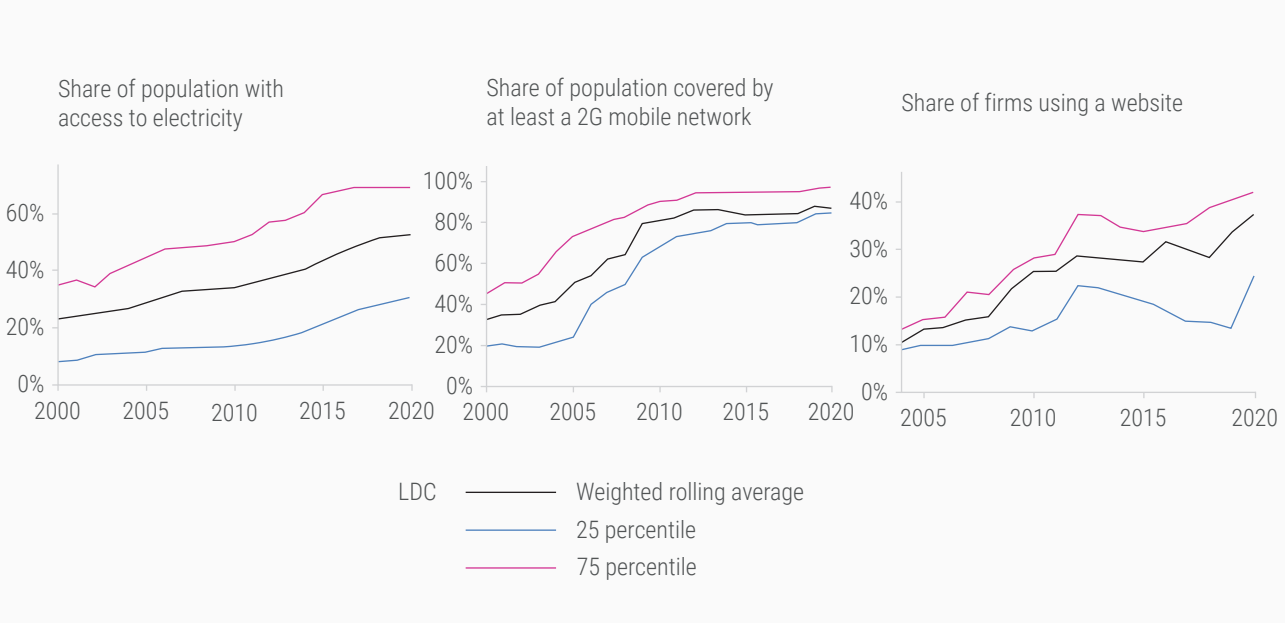
Latecomers from the least developed countries and emerging countries also have the potential to break away from the original strategic development path and create new approaches that bypass the intermediate stages of technology through which countries have historically passed during the development process to achieve higher societal impacts. Indeed, by constantly upgrading technology and fully using resources, and notably thanks to the rise in digital technologies, latecomers can sometimes achieve faster growth and create their own path, in a process known as "path creation", "path skipping" or "leapfrogging". A successful catch-up process offers least developed countries an opportunity to climb the ladder in the global technological hierarchy and contribute to the generation of knowledge and new technology. Some leapfrogging opportunities available to the least developed countries offer a less costly investment in infrastructure compared with traditional technological paradigms. Renewable energy technologies as well as ICT eliminate the need for costly infrastructure investments such as landlines, extensions of the national energy grid and the creation of financial branches in remote areas. In its most advanced form, leapfrogging could mean developing a services-led economy by skipping manufacturing.

The energy sector is a good example to illustrate how latecomers can achieve faster growth by skipping certain technical stages. The least developed countries can seize the opportunity to pursue zero-carbon pathways that respond to people's needs and to re-orient their energy and development trajectories towards what is sustainable and beneficial for both climate and development (such as renewable energies), rather than getting trapped in unsustainable and costly systems (such as the use of fossil fuels). Renewable energies could be considered a viable solution that contributes to development, climate and economic benefits. The least developed countries can show leadership in the field of climate by collectively increasing the share of modern renewable energy in their energy mix. This can set an example and put moral pressure on the emerging and developed countries.

Figure 8 provides an overview of the considerable technology progress that the least developed countries have made over the past decades (2000–2020). For the share of population with access to electricity, the indicators show that the increase in access is a trend that is developing in an equal way across the least developed countries. For the share of population covered by a 2G network, the upward trend has stabilized over the past 10 years, with 85 per cent of countries covered. Lastly, for the share of firms using a website, there are differences visible in the progress over time across the least developed countries. The trend is still upward, but there seem to be countries lagging behind, including Eritrea, Sierra Leone and Guinea-Bissau.

63 World Intellectual Property Organization (WIPO), *The Informal Economy in Developing Nations: Hidden Engine of Innovation?* (Cambridge: Cambridge University Press, 2014).

Figure 8. Progress on technology headline indicators



Source: SE4ALL, ITU, World Bank Enterprise Survey. Visualization by Technopolis.

Outlook: e-gov and the uptake of the Fourth Industrial Revolution technologies

In the post-COVID-19 era, technologies will play a decisive role in sustainable development, as the pandemic has highlighted developed countries' excessive dependence on key supplies, thus encouraging these advanced economies to reverse their decision to delocalize production to the least developed countries. More productive firms that are integrated into international systems could build on the digital transformation by using technologies such as big data, the Internet of things, blockchain or artificial intelligence to help enhance their productivity and competitiveness.

Another potential benefit of the Fourth Industrial Revolution is the use of blockchain for services, which provides opportunities for the least developed countries in the area of "e-government"/"e-gov" and digital public goods.[64] A grand vision of blockchain technology is the creation of Government 2.0, a new version of governmental structures and cultures. Here, blockchain offers the possibility to decentralize some government functions (e-government and "government as a service"). This includes national record-keeping in contexts where citizens have low levels of trust in both Government and the payment of government workers' salaries.

For the least developed countries, taking part in the race to digitization implies tackling many challenges, as they are at a disadvantage and risk being excluded from the global discussion of how to address them. The associated risk of disregarding the need to build manufacturing capabilities and foster new skills could see the least developed countries excluded from the benefits of the Fourth Industrial Revolution.[65]

64 Technopolis, Research ICT Africa and Tambourine Innovation Ventures, *Potential of the Fourth Industrial Revolution in Africa: Study Report – Unlocking the Potential of the Fourth Industrial Revolution in Africa* (Abidjan, African Development Bank, 2019). Available at https://www.technopolis-group.com/wp-content/uploads/2020/02/Potential-of-the-fourth-industrial-revolution-in-Africa.pdf.

65 United Nations Industrial Development Organization (UNIDO), *Industrial Development Report 2020: Industrializing in the Digital Age* (Vienna, 2019).

However, the impact of adopting Fourth Industrial Revolution-related technology raises new concerns related to democracies, the spread of fake news, information control and privacy, as well as data ownership (a new asset for competitiveness with the rise of big data) and cybersecurity. Giant global data players (such as Facebook, Google, Amazon) benefit from several advantages, which raises regulatory and governance issues.[66]

A second matter of concern is employment and skills. While the Fourth Industrial Revolution promises productivity gains, the least developed countries must address youth unemployment and informal jobs and are at risk of seeing jobless growth worsening the status quo. Moreover, due to technologies replacing employees' manual routine tasks, the labour force is under pressure to develop transversal skills to complement technical skills.[67] Artificial intelligence, machine learning and automation are likely to exacerbate inequalities between least developed countries and advanced countries, as these technologies could replace the workforce both in decision-making and task realization.[68]

While more research is needed to establish how this impact will play out across sectors and technologies,[69] political decisions must minimize labour-market distortions while welcoming new technologies. These decisions must also foster the creation of innovative firms, as structural transformation in the least developed countries will require job creation by more innovative companies, including to absorb employees from the informal sector (the most impacted by automized processes).[70]

Photo credit: Marcel Crozet, ILO

66 United Nations Inter-Agency Task Team on Science, Technology and Innovation for the SDGs and European Commission, Joint Research Centre, *Guidebook for the Preparation of Science, Technology and Innovation (STI) for SDGs Roadmaps* (Luxembourg, Publications Office of the European Union, 2021). Available at https://sustainabledevelopment.un.org/content/documents/26937Guidebook_STI_for_SDG_Roadmaps_final_Edition.pdf.

67 United Nations Conference on Trade and Development (UNCTAD), *The Least Developed Countries Report 2020: Productive Capacities for the New Decade* (New York, 2020).

68 UNCTAD, *Technology and Innovation Report 2021: Catching Technological Waves – Innovation with equity* (New York, United Nations publication, 2021).

69 Edward Lorenz and Erika Kraemer-Mbula, The impact of adopting 4IR- related technologies on employment and skills: The case of automotive and mining equipment manufacturers in South Africa. In *Leap 4.0: African Perspectives on the Fourth Industrial Revolution*, Zamanzima Mazibuko-Makena and Erika Kraemer-Mbula, eds. Mapungubwe Institute for Strategic Reflection (2020).

70 UNCTAD, *The Least Developed Countries Report 2018: Entrepreneurship for Structural Transformation – Beyond Business as Usual*. Sales No. E.18.II.D.6. (New York and Geneva, 2018).

3.3 Emerging innovation systems: a strong entrepreneurial base

Innovation as final step in converting knowledge into economic and societal value is key for least developed countries wanting to capture value from their investments in science and technology. The status of innovation is captured by the selected innovation indicators that track gross expenditure on R&D as a share of GDP, share of firm spending on R&D, share of firms introducing new-to-the-firm innovation and number of patents granted per million capita.

Commitments to building the national innovation systems are made at the political level, and this is captured in the case studies. However, these commitments translate into how the innovation system is performing and how much the Government is spending on R&D, as this investment in STI is necessary for innovation to take place.

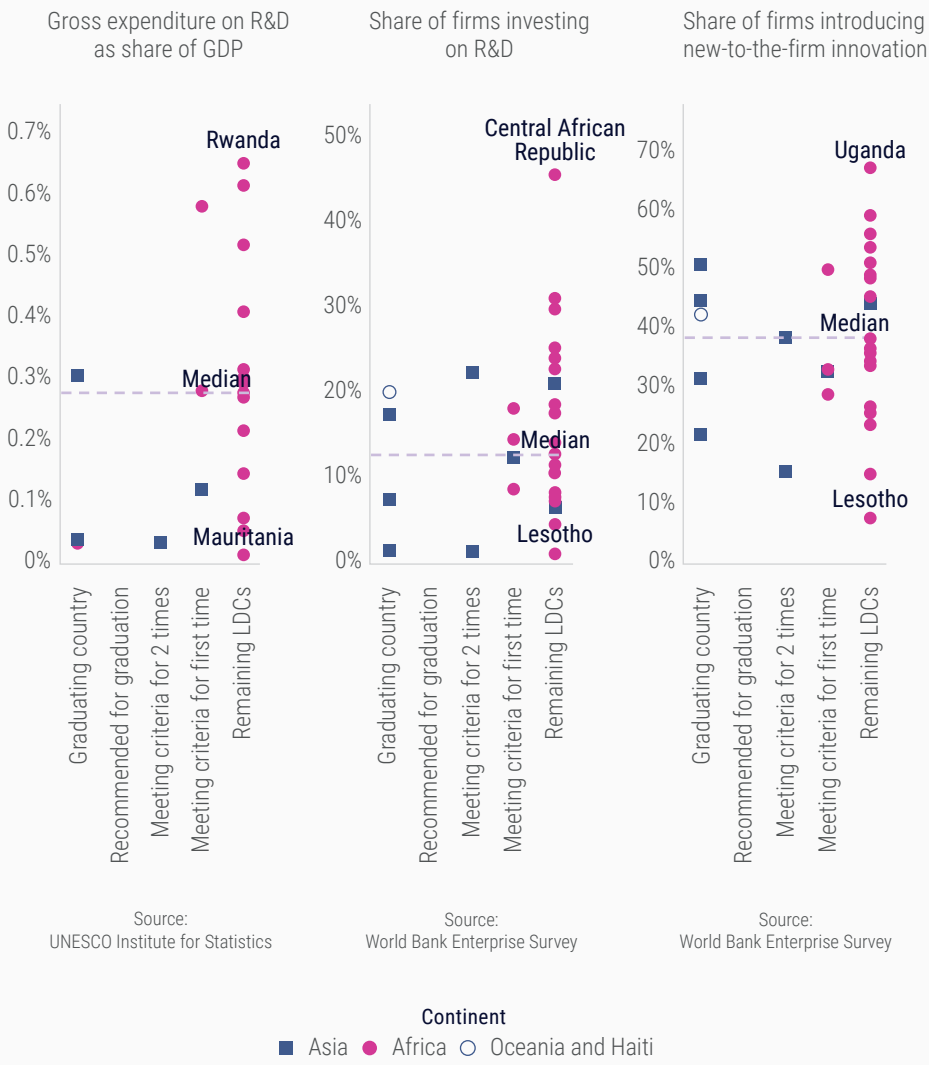
Based on country-level data, case study insights, and qualitative evidence from interviews and literature, the state of innovation (Table 4 and Figure 9) is discussed in the following sections.

Table 4. Overview of state of innovation in the least developed countries

	Firms that spend on R&D (%)	Firms that introduced innovation new to the firm (%)	Growth of innovative companies (scale 1-7 (highest))	Granted patents (no. per million capita)	Funded start-ups in crunchbase	Attitude towards entreprenar-ial risk (scale 1-7 (highest))	Share of firms engaging in R&D-based innovation (%)	Share of firms engaging in non-R&D-based innovation (%)
Average, all countries	17.1%	37.5%	4	214.3	-	4	14.2%	33%
LDCs (mean)	16.1%	38.4%	3.6	1.1	106	3.5	13.3%	39%
Average, LDCs meeting criteria for first time	25%	38%	4	1.3	82	3.8	19%	35%
Average, LDCs meeting criteria 2 consecutive times	8.4%	25.7%	-	0.0	104	-	6.9%	38.0%
Average, LDCs recom-mended for graduation	-	-	-	18.3	0	-	-	-
Average, LDCs scheduled for graduation between 2023 and 2026	9.4%	34.1%	3.6	0.4	391	3.6	8.7%	45%
Average, remaining LDCs	16%	41%	3.5	0.7	52	3.5	14%	38%

Sources: Group estimates based on data from the World Bank Enterprise Survey (WBES) and World Intellectual Property Organization (WIPO).

Figure 9. Strip plot of innovation indicators for the least developed countries



Inputs: limited explicit R&D and a mixed support landscape

At the firm level, the share of firms in least developed countries likely to invest in R&D (16.1 per cent, see Figure 9) is almost equal to the world average (17.1 per cent). This shows that product and process improvements are perceived as important by entrepreneurs and firm managers around the world. However, qualitative evidence and the literature highlight that firms in least developed countries are more likely to engage in informal R&D (time spent by an employee) rather than formal R&D, with the innovation likely to be less novel. A key limitation here is sufficient access to capital (internal or external) for larger R&D investments that require large cash outlays, making it more difficult to engage in more ambitious R&D projects. The overall high degree of uncertainty makes entrepreneurs in least developed countries slightly more risk-averse compared with the world average. In sum, firm leaders in the least developed countries are actively engaging in R&D, but operate in a context in which it is difficult to bring more scale to their R&D projects.

In terms of enterprise support organizations, business incubators provide a full-scale range of services to innovative start-ups such as training, mentoring, office space and venture capital financing. Some least developed countries such as Bangladesh, Burkina Faso, Burundi, Haiti, Madagascar, Mozambique and Rwanda consider their current set-up to be strong. In other least developed countries, an insufficient number of business

incubators or disorganization due to a lack of capacities and financing constitute common obstacles.

Innovation hubs are also key for sharing experiences and best practices in countries such as Burkina Faso, Burundi, Haiti, Madagascar, Malawi, Rwanda and Zambia. Rwanda has the highest number of innovation hubs in Africa, while Zambia intends to use innovation hubs to capitalize on informal innovation. Insufficient innovation hubs are perceived as an obstacle, with only one in Lesotho, for instance. This can be due to the lack of funding, as outlined by Nepal and the United Republic of Tanzania. Furthermore, innovation hubs are often poorly equipped (as reported by the United Republic of Tanzania and Ethiopia) and lack coordination. Hub networks help circulate knowledge and act as catalysts, such as AfriLabs in Africa.[71] Insights from recent major studies show that innovation hubs need time to build capacity, as the small share of successful scale-up leaders are the best mentors for future generations of entrepreneurs.[72]

In terms of the external support environment for innovation, a mixed picture emerges. On one hand, about half of the least developed countries enjoy relative ease in doing business. In The Gambia for instance, existing regulations make it easy to do business in the country; it is possible to register a business in less than a day. Similarly, in the Democratic Republic of the Congo, the new Investment Code provides legal security for companies and promotes the rule of law. In Malawi, the Department of the Registrar General which is responsible for registering new businesses and enterprises will be transformed into the Companies and Intellectual Property Office to allow for rapid registration of businesses while respecting intellectual property rules. On the other hand, other least developed countries are still facing considerable challenges in terms of the business climate, and the lack of synergies among national institutions and regulatory actors constitutes a major obstacle. Access to finance, particularly for innovation, remains another key bottleneck.

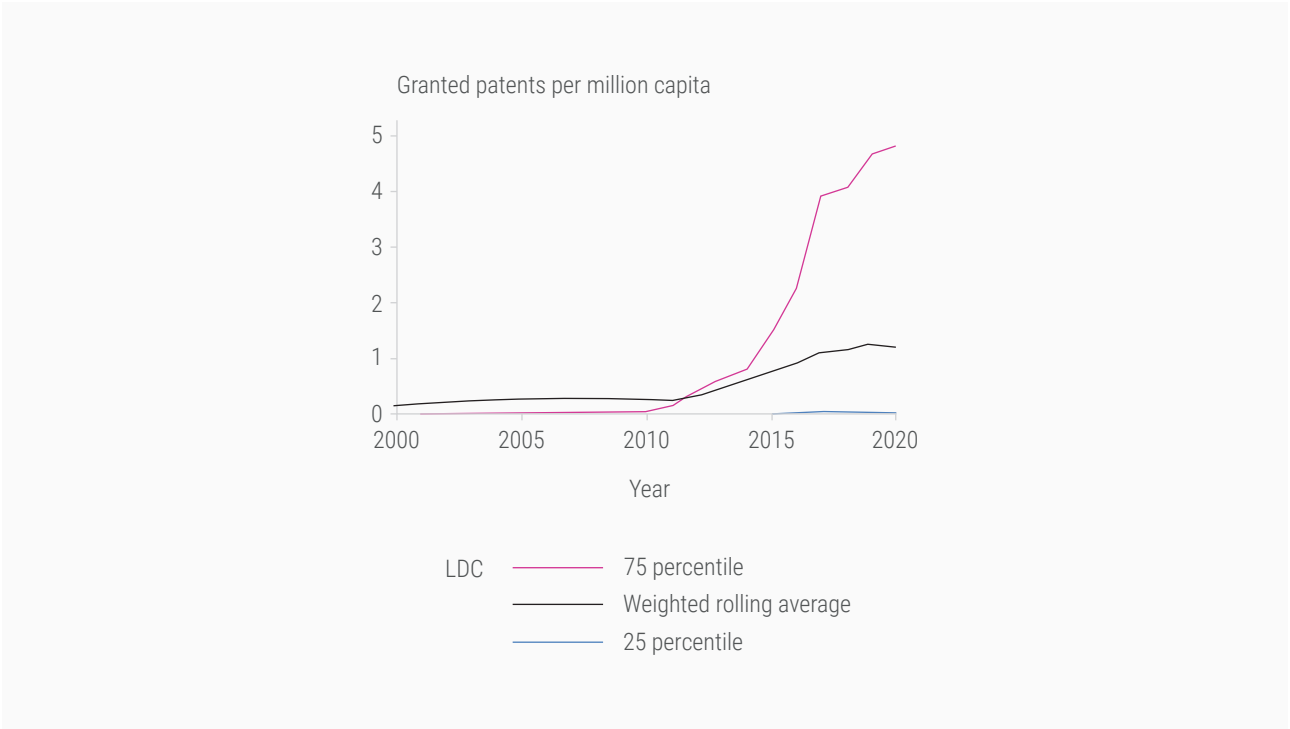
Throughput: high degree of innovation, but mostly internal to the firm

The high degree of engagement with R&D does indeed translate into a high rate of innovation within firms in the least developed countries. Firms in these countries are as likely as those in other countries worldwide to have introduced an innovation that is new to the firm (38 per cent in the least developed countries and 37 per cent as the global average; see Figure 10). This fact once again highlights that firms in the least developed countries are highly engaged in innovation. However, a similar pattern emerges: while the degree of innovation is high, the degree of formalization and novelty of these innovations (proxied by patents) remains very low (1.13) compared with the world average (214.3). However, over the period 2000 to 2020, patenting in the least developed countries rose steeply in the 75-percentile from 2012 onwards, with the average for all least developed countries growing moderately from 2012 onwards. Yet, the 25-percentile remained rather low over the years, indicating that that while in some countries patentable innovation is gaining traction, many countries still need to begin this journey.

Even though most least developed countries have increased their R&D expenditure, progress remains low. For example, although the African Union established a target of 1 per cent of GDP, on average sub-Saharan countries are still at 0.38 per cent.[73] Overall, in least developed countries, very little of R&D expenditure is funded by the private sector to develop industrial technologies for production. Moreover, the private sector in the least developed countries is dominated by small enterprises, very often with limited technical and financial resources, making them less inclined to innovation than medium-sized enterprises (product innovation) and large firms (process innovation). For instance, Mozambique and Ethiopia demonstrate the need for a clear policy and strategy from the Government to establish partnerships with the private sector. However, some least developed countries perform better than others: Bangladesh is looking to improve production process sophistication, innovation capacity, company spending on R&D, and university–industry collaboration in R&D.

71 AfriLabs is a network organization supporting innovation centres that provides support to innovators and entrepreneurs across African countries since 2011. It was founded with the mission of building a community around the rapidly emerging technology hubs in Africa. For more information, please see https://afrilabs.com/.
72 See, for example, https://endeavor.org/wp-content/uploads/2021/09/Fostering-Productive-Entrepreneurship-Communities.pdf.
73 UN-OHRLLS, Landlocked Developing Countries and Small Island Developing States (UN-ORHLLS), *State of the Least Developed Countries 2021: Building Back Better in Response to COVID-19* (2021). Available at https://www.un.org/ldc5/sites/www.un.org.ldc5/files/pdf/stateLDC_2021/stateldc_2021.pdf

Figure 10. Progress on innovation headline indicator: patents granted per million capita



Source: WIPO.

Output: constrained growth

The main intended result (output) of innovation is to renew companies at the micro and macro levels, resulting in increased productivity, welfare and growth. At the micro level, firms upgrade their products and processes, resulting in higher productivity and possibly export-led growth. At the macro level, firms that innovate successfully grow faster than those that do not, thereby renewing the entire company landscape over time. While precise data are lacking, the Global Competitiveness Index shows that the least developed countries score somewhat lower (3.5) compared with the world average (4) on a seven-point scale. In terms of funded start-ups, another proxy variable for fast growth, the number of funded start-ups remains relatively modest (around 106 in total per country, and 4,906 start-ups in total in all least developed countries together). There is a pattern visible in terms of graduation level, although the pattern is weak: the closer to graduation, the more start-ups there are on average in the least developed countries. The countries that have met criteria for two consecutive times are excluded from this pattern. The weakness of this pattern could be due to the fact that funded start-ups are associated with country size, international networks and innovation hub activity, all of which are not necessarily directly correlated with development level.

The most fundamental building blocks that least developed countries require to develop their STI systems are i) an increase in the capacity of domestic private sector companies to utilize new technologies – in other words their absorptive capacities – and ii) strengthening of domestic actors and knowledge systems through skills development and networking, which will contribute to the creation, accumulation, use and sharing of knowledge.[74] Therefore, least developed countries must mobilize all talents to reach the ambitions of meeting the SDGs.[75] This includes the private sector, government bodies and knowledge systems.

However, many of the crucial components of entrepreneurship are still missing in all least developed countries, and those that do exist are undermined

74 UNCTAD, *Achieving the Sustainable Development Goals in the Least Developed Countries: A Compendium of Policy Options* (New York and Geneva, United Nations publication, 2018).
75 UNESCAP, *Science, Technology and Innovation for Sustainable Development in Asia and the Pacific: Policy Approaches for Least Developed Countries* (Bangkok, United Nations publication, 2016). Available at https://www.unescap.org/sites/default/d8files/knowledge-products/STI-LDCs%20book.pdf.

by low risk-acceptance, a lack of access to flexible funding opportunities, a lack of networking and cultural support, as well as a lack of start-up skills.[76] In particular, the lack of access to flexible funding at the earliest and riskiest stages of business creation remains a challenge. However, countries such as Burkina Faso, Burundi, Ethiopia, Haiti, Malawi, Senegal, Uganda and Zambia display above-average capacities. While most investments come from the public sector, there is a need for greater public sector involvement to help create demand for innovation and foster competition.

Outlook: a strong entrepreneurial foundation for innovative growth

The main findings of this study point in a clear direction. Perhaps contrary to expectations, entrepreneurs and firm managers in the least developed countries are highly engaged in innovation, invest in R&D and introduce high rates of innovation in their firm. However, both R&D and innovation outputs are relatively informal and modest in scope, due to a lack of access to finance, institutional maturity and access to international markets. This means that there is a fertile ground for productivity increases through technology adoption (see also the next section), but that innovation-driven growth through export still requires heavy investment and the evolution of institutions (such as protection of intellectual property), frameworks and support in the years to come. A promising development in this regard is the rapid increase in private and community-led innovation hubs that support entrepreneurs, which rapidly increase the quantity and quality of innovations.

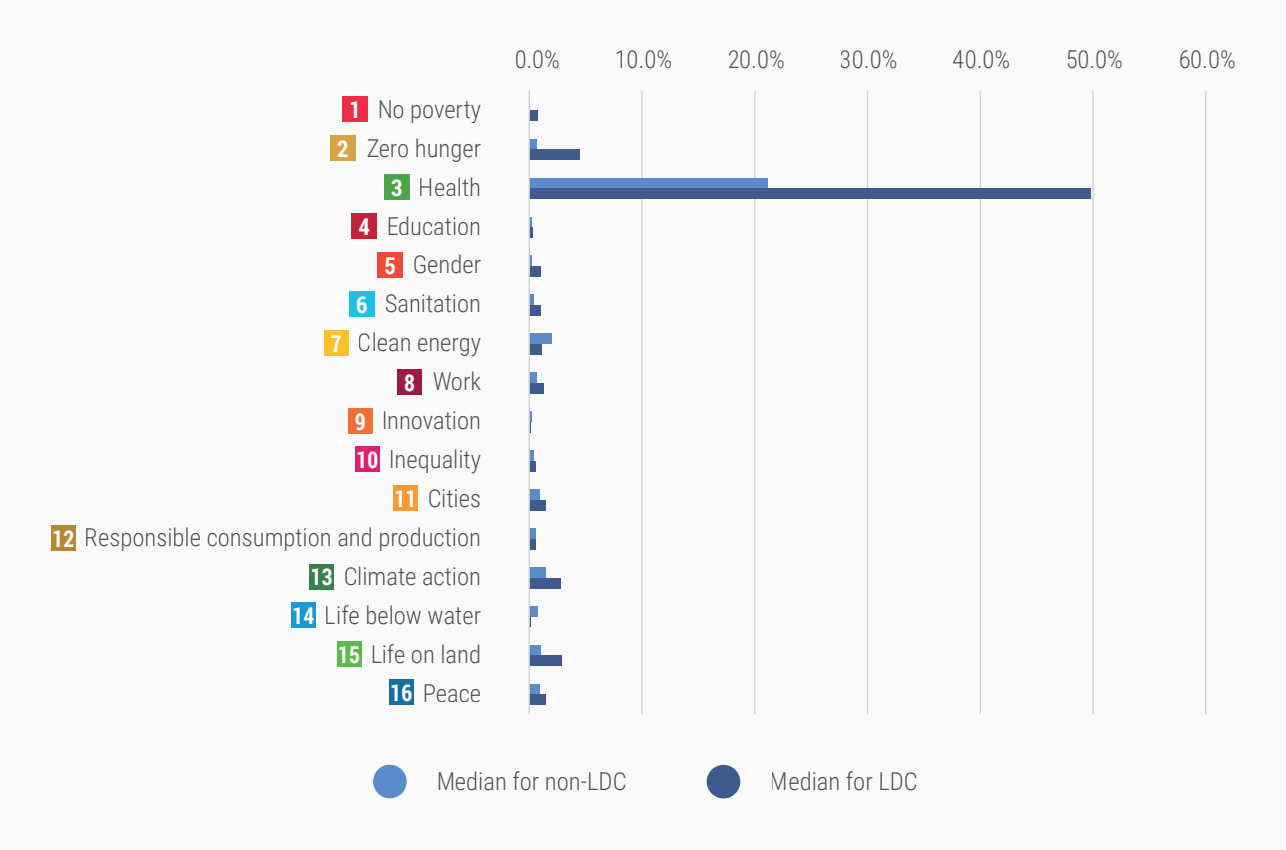
3.4 Global challenges and STI: science and innovation focus on SDGs

The past decade has seen the global goals and their interaction with STI evolve greatly. First, the introduction of the SDGs in 2015 characterized a shift away from a narrow set of specific targets focused on developing countries only, to a new global common agenda for humanity. Secondly, for the first time this agenda explicitly recognized the role of science and innovation. Science and innovation policymakers, as well as researchers and innovators themselves, are responding by increasingly orientating themselves to these global goals, with the intention of contributing new knowledge and solutions to address the related challenges. For the least developed countries, which suffer disproportionately from the challenges set out in the SDGs and which have limited resources, a strategic investment agenda of STI in order to work towards the SDGs is of utmost importance.

Based on a keyword assessment of publications, Figure 11 shows a striking finding regarding the focus of science production on SDGs in the least developed countries. First, one can conclude that scientists in the least developed countries focus very heavily on SDGs in their work: 71 per cent compared with the global average of 31 per cent. The vast majority of scientific work carried out by scientists in the least developed countries is directly relevant to the SDGs. A very large share of that is focused on Good Health and Well-Being (50 per cent, SDG 3), which is also the largest category at the global level, but even more so in the least developed countries. Other major topics include Zero Hunger (SDG 2), Climate Action (SDG 13) and Life on Land (SDG 15). Interestingly, the only categories where the least developed countries are relatively less focused are Affordable and Clean Energy (SDG 7) and Life Below Water (SDG 14).

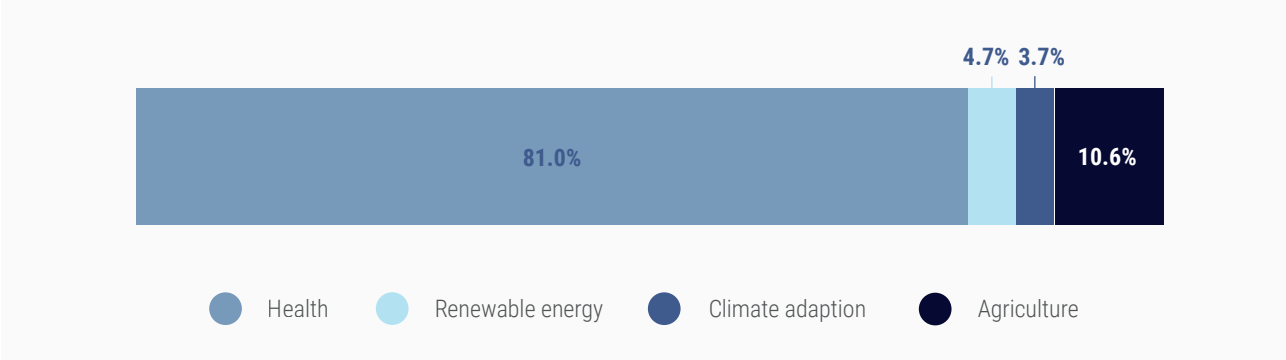
76 UNCTAD, A *Framework for Science, Technology and Innovation Policy Reviews: Harnessing Innovation for Sustainable Development* (Geneva, 2019). Available at https://unctad.org/system/files/official-document/dtlstict2019d4_en.pdf.

Figure 11. SDG focus of scientific outputs



Source: Based on text-analysis of abstracts in SCImago database.

Figure 12. Thematic focus of crunchbase investments in the least developed countries



For innovation, fewer data are available, but an analysis of the focus of funded start-ups (Figure 12) again shows health strongly dominating in the least developed countries, with 81 per cent of funded start-ups focusing on that theme. Agriculture comes second, with 10.6 per cent.

In terms of policies and investment, there are shifts regarding the STI initiatives financed in developing countries, and more specifically in the least developed countries. The first shift is away from basic research and towards big science. Indeed, to solve pressing development challenges and reach the SDGs, the focus of scientific discovery has shifted from basic research to "relevant" or big science. The shift in research priorities towards a focus on big science can be witnessed in the amount of research funds allocated to applied science. Researchers are investing more than before in turning a discovery into a commercially viable product or technology with high socioeconomic impacts. Several foundations and NGOs have launched competitions and funded prizes to encourage commercially viable innovations that can help address societal challenges. For instance, the Bill & Melinda Gates Foundation has awarded several grants through the Grand Challenges to initiatives focusing on health in the least developed countries, such as a study to assess the effects of social inequalities of the COVID-19 crisis in low-to-middle-income countries. However, it is important to note that in 2020, 80 per cent of countries were still investing less than 1 per cent of GDP in R&D.

The second shift relates to the focus on citizen engagement and implication in the STI initiatives that are funded. The best way to identify citizens' needs and challenges and to find sustainable solutions to serve their interests is to involve the citizens themselves and engage them in the development process. No good can come from open data without citizen engagement. Local needs must be recognized if a development technology from developed countries is to be adapted to the local context. Public participation will encourage the gradual establishment of educated citizens and enhance the role played by citizens in transformative innovation and positive change.

Consequently, this will contribute to more connections between science, policy and citizens and will lead to greater transparency and accountability. Various international actors (including United Nations organizations, international and regional organizations, as well as NGOs) have funded exchange platforms and created networks that are open not only to the national bodies and the private sector, but also to the general population. An example of such an initiative is the Africa Regional Science, Technology and Innovation Forum, the third edition of which was held in February 2021 in the Congo. The second edition, organized in 2020 in Zimbabwe, attracted more than 800 delegates, representing the United Nations, African member states, civil society, young people, the private sector and marginalized people. Following the forum's second edition, several key actions were undertaken such as the organization of the first Africa Nanotechnology Research and Innovation Forum and the launch of the first online youth bootcamp on innovation for COVID-19 with students from 38 African countries.

Finally, there is a shift in how initiatives are formulated to overcome global knowledge gaps. Actors are moving away from a one-way delivery mechanism based on a linear model of knowledge transfer towards more inclusive mechanisms and multidirectional models which feature new characteristics, such as result-oriented research. The integration of local and indigenous knowledge at the global science–policy interface will reverse the dynamic whereby least developed countries are only at the receiving end of knowledge transfers.

3.5 Specific features of STI in the least developed countries

The least developed countries, while each being unique in their specific characteristics in terms of STI institutional arrangements and policies, share a number of similar features that are quite prominent in their societies. A high degree of informality, the role of indigenous knowledge, and the important role of the diaspora were identified as key issues that are of particular importance for STI performance and related economic transformation. While these aspects are certainly not unique to the least developed countries, they are of particular relevance to them. In addition, two specific kinds of innovation that are particularly prevalent in the least developed countries – frugal and grass-roots innovation – are highlighted.

The least developed countries are characterized by a high degree of informal firms. Informality has a complex relationship with innovation performance. First, informality brings many challenges, including access to financial markets and regulatory uncertainty, and research has shown that it is associated with reduced process innovation.[77] On the other hand, informal actors

77 Pedro Mendi and Robert Mudida, "The effect on innovation of beginning informal: Empirical evidence from Kenya", *Technological Forecasting and Social Change*, vol. 131(C) (2018).

operating in communitarian contexts show a high degree of resilience due to a high degree of informal insurance,[78] meaning that they are more resilient in the face of economic and technological shocks, boosting their agility to innovate.

Indigenous knowledge and culture

Indigenous knowledge and culture are an asset for the least developed countries, which can capitalize on this alternative source of knowledge to help achieve sustainable outcomes. Indigenous knowledge systems are often dynamic, as they can be renewed and transmitted by each new generation, and the role of such knowledge at the global level is gaining more recognition.

The scientific literature suggests that scientific and indigenous knowledge are interconnected and complementary, rather than opposing forces.[79] Biodiversity, climate and natural risk preparedness are a few of the domains in which the role of indigenous knowledge has been demonstrated. For instance, Andean farmers' observation of the Pleiades constellation enabled them to predict El Niño with an accuracy comparable to that of modern meteorological science based on computer modelling. Interestingly, indigenous peoples are increasingly playing a role in formulating policies (see Box 4).

Box 4. Voices in STI

Indigenous peoples are not just beneficiaries of modern STI; they also have the knowledge and capacities to enhance and create it.[80] They have therefore been involved in the United Nations' TFM from the outset. Indeed, an indigenous representative (Dr. Mirna Cunningham, Miskito from Nicaragua) formed part of the first 10-member group appointed by the United Nations Secretary-General Ban Ki-moon for the period 2016–2017. Results are yet to be collected and analysed.

Creating synergies between indigenous and traditional knowledge[81] and local technologies to address global challenges in least developed countries will encourage a new approach that supports the development of local and domestic capabilities to fully capitalize on and exploit technology transfer. This implies moving away from the hierarchy of frontier technology transferred at the top and the processes of imitation and incremental innovation at the bottom,[82] towards adopting a rather inclusive type of innovation that has the potential to involve a portion of the population that is often not included in STI.

Capitalizing on networks with diaspora communities is the main way in which the least developed countries can limit the damage of "brain drain" and derive gains from it by developing interconnected knowledge economies. On the one hand, the least developed countries' investment in developing human capital is lost when highly skilled and educated workers migrate. On the other hand, least developed countries can benefit from high-skilled migration if partnerships between sending and receiving countries promote the repatriation of the skills and knowledge phenomenon, thus leading to "brain circulation". Diaspora networks in the least developed countries can play a fundamental role in the development of knowledge economies. When skilled personnel

78 Paulo Santos and Christopher B. Barrett, "Informal insurance in the presence of poverty traps: Evidence from Southern Ethiopia", *SSRN* (May 2006). Available at https://doi.org/10.2139/ssrn.998541.
79 See for instance Erin L. Bohensky and Yiheyis Maru, "Indigenous knowledge, science, and resilience: What have we learned from a decade of international literature on "integration"?", *Ecology and Society*, vol. 16, No. 4 (2011). Available at http://www.jstor.org/stable/26268978.
80 United Nations Department of Economic and Social Affairs: Indigenous Peoples, "STI Forum Session 8: indigenous peoples, traditional knowledge, and the Sustainable Development Goals", 16 May 2019. Available at https://www.un.org/development/desa/indigenouspeoples/news/2019/05/sti-forum-session-8-science-technology-and-innovation-of-indigenous-peoples-culture-and-traditional-knowledge-and-the-achievement-of-the-sustainable-development-goals/ (accessed on 16 July 2021).
81 As outlined in the UNESCO Science Report (UNESCO, 2015), p.15, "Several terms co-exist in the published literature. They include indigenous knowledge, traditional ecological knowledge, local knowledge, farmers' knowledge and indigenous science. Although each term may have somewhat different connotations, they share sufficient meaning to be used interchangeably."
82 UNESCAP, *Science, Technology and Innovation for Sustainable Development in Asia and the Pacific: Policy Approaches for Least Developed Countries* (Bangkok, United Nations publication, 2016). Available at https://www.unescap.org/sites/default/d8files/knowledge-products/STI-LDCs%20book.pdf.

return home, temporarily or permanently, they bring with them new technologies and knowledge from developed countries. To capitalize on the potential of "brain gain", an increasing number of actors focus on the "scientific diaspora", such as the Carnegie African Diaspora Fellowship Program. Moreover, the least developed countries can benefit from scientific investments in other countries via scientific collaboration through diaspora networks.

Frugal and grass-roots innovation

Frugal innovation can be an important window of opportunity for the least developed countries to ensure the social well-being and sustainable livelihoods of their populations. It can be defined as an innovation that generates considerably more business and social value while significantly reducing the consumption of scarce resources. The paradox of "doing more with less" is therefore at the heart of this type of innovation. A recent study estimated that around 10 per cent of innovations in developing and emerging countries can be classified as frugal innovation.[83]

It is worth noting that firms of all sizes and across all fields employ frugal innovation methods, which use only basic technologies (if any) and require only minimal capital investment (if any). This includes start-ups, companies and also multinationals. Frugal innovation does not always involve new investments or technology; it can be an innovation in the way the supply chain is organized. The first type of innovation is called Jugaad, which is a colloquial Hindi word that translates as an improvised and innovative fix, often born from ingenuity to respond to local needs. The second type is Jhakaas innovation, which is more elaborate and sophisticated but still born from frugal thinking. This type of innovation has the potential to disrupt even the markets of developed countries. For instance, the portable electrocardiogram (ECG) machine redesigned for rural India costs US$1,000 instead of US$10,000. By encouraging and promoting frugal innovation skills, Governments from the least developed countries can support the creation of cost-effective innovations that could benefit society as whole.

Grass-roots innovation is a key asset that the least developed countries can use to respond to development challenges. The term "grass-roots" means "non-mainstream" or "non-dominant". As grass-roots innovators are often direct users of their innovations, they have a better understanding of their environmental and social needs than external actors. This type of innovation is not led by the Government but is a spontaneous self-organized and self-generated system of knowledge creation. It involves actors such as local communities or NGOs in the process of capitalizing and using knowledge to overcome development challenges, which are often defined at the local level.

> **Grass-roots innovators, especially in the least developed countries, need assistance with protecting and developing their ideas to diffuse them more widely to various actors such as academics and practitioners.**

Collaborations with the private sector as well as research centres can provide the scale and expertise needed to achieve higher impacts. For instance, the MIT D-Lab based in the United States of America engages in effective co-creation by collaborating with low-income groups in developing countries to adapt innovations to local needs. Fieldwork, research, and innovation practices are undertaken in Burkina Faso, Nepal, Rwanda, the United Republic of Tanzania, Uganda and Zambia.

Another example of grass-roots innovation is the maker movement, which contributes to informal innovation in various sectors such as robotics and digital fabrication.[84] This movement encourages information-sharing, free information and open-source technologies to support equitable access to information and technologies. As maker spaces lack funding, re-use and open-source hardware and software can be helpful.

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83 Matthias Ploeg and others, "Rare gems or mundane practice? Resource constraints as drivers of frugal innovation", *Innovation: Organization and Management*, vol. 23, No. 1 (8 October 2020). Available at https://doi.org/10.1080/14479338.2020.1825089.

84 See, for instance, Adrian Smith and others, *Grassroots Digital Fabrication and Makerspaces: Reconfiguring, Relocating and Recalibrating Innovation?* University of Sussex, SPRU Working Paper Series, SWPS 2013–02 (2013).

3.6 An evolving policy landscape

In many least developed countries, national innovation systems are currently disarticulated. There is a large range of actors from both the formal (private sector, Government, research centres, academic institutions, private sector, not-for-profit sector) and informal sector (grass-roots innovators, local and indigenous knowledge holders, citizen scientists) involved in knowledge creation and exchange, but the flow of information and knowledge exchange is suboptimal and not very well integrated.[85] This calls for strong governance of the STI systems. This study shows that the best-performing least developed countries often display a more structured governance (through political willingness, clear institutions and roles, clear policies and strategies).

The survey conducted among the 46 least developed countries shows that often multiple authorities and/or ministries oversee STI. The majority of least developed countries that responded to the survey have mandated line ministries for STI in their country that are either dedicated to (higher) education, ICT/telecommunication (including digital development) or research. An increasing number of least developed countries has quite recently set up dedicated ministries to STI (e.g. Angola, Cambodia, Democratic Republic of the Congo, and Myanmar) or a national science and technology council/institute/commission for STI policy (e.g. Benin, Rwanda, United Republic of Tanzania and Timor-Leste). A few least developed countries do not even have a mandated STI authority.

The lack of human and financial resources, alongside corruption and political instability, are the main impediments to building national innovation systems and prioritizing STI in government interventions. Against this backdrop, the least developed countries have achieved some progress in terms of planning, programming, budgeting, promoting and financing STI policies and plans. To date, about half of the least developed countries that responded to the survey have a national STI policy or plan. In many other least developed countries, a national STI policy or plan is currently in development (Benin; Democratic Republic of the Congo; Haiti; Senegal; Timor-Leste; Togo; Uganda).

Table 5. Type of mandated STI organization in the least developed countries

Type of mandated STI organization	Responses (*)	Countries
Dedicated STI ministry	4	Angola; Cambodia; Democratic Republic of the Congo; Myanmar
Ministry	19	Bangladesh; Benin; Burkina Faso; Burundi; the Comoros; Ethiopia (2 ministries); The Gambia; Lao People's Democratic Republic; Lesotho; Madagascar; Malawi; Mozambique; Nepal; Niger; Rwanda; Senegal; Togo; United Republic of Tanzania; Zambia
National council/institute/commission	4[86]	Benin; Burundi; Rwanda; Timor-Leste; United Republic of Tanzania
Other	3	Haiti; Lao People's Democratic Republic; Uganda
None	1	Kiribati

Source: Survey conducted in the 46 least developed countries. The table shows the responses of the 25 least developed countries that responded to this survey.

85 Susan Schneegans, Jake Lewis, and Tiffany Straza, eds. *UNESCO Science Report 2021: The Race Against Time for Smarter Development* (Paris, United Nations Educational, Scientific and Cultural Organization, 2021).
86 Other national authorities may exist, but they were not referenced as the mandated STI authority in this survey

Table 6. Overview of STI policies or plans per country

Country	Official document name	Year of publication	Period of validity
Bangladesh	National ICT Policy	2018	2021
Burkina Faso	Politique sectorielle de la recherche et de l'innovation (PSRI)	2018	2027[87]
The Comoros	Stratégie Comores Numérique 2028	2020	Not stated
The Gambia	National Science, Technology and Innovation Policy of The The Gambia	2015	10 years
Nepal	National Science, Technology and Innovation Policy 2019	2019 (3rd edition)	10 years (review thereafter or upon request)
Niger	Politique Nationale en Science, Technologie et Innovation (POSTINI)	2020	Permanent
Rwanda	Science, Technology and Innovation Policy	2020	Not stated
Zambia	National Science, Technology and Innovation Policy	2020	5 years
Angola	Política Nacional de Ciência, Tecnologia e Inovação de Angola	2011	Not stated
United Republic of Tanzania	National Science and Technology Policy	1996	Still valid but under review
Ethiopia	Science Policy and Strategy of Ethiopia	2012	Still valid but under revision
Burundi	Politique Nationale de la Recherche Scientifique et de l'Innovation Technologique	2011	7 years
Lao People's Democratic Republic	National ICT Policy 2009	2009	5 years
Malawi	National Science and Technology Policy	2002	18 years, targeting the Malawi Vision 2020
Mozambique	National Policy of Science and Technology; Science, Technology, and Innovation Strategy	2003, 2006	10 years
Lesotho	Lesotho Science and Technology Policy	2006	5 years

Source: Technology Bank survey 2021.

87 This date was not provided but could be traced on the government website.

Political willingness, a strong institutional set-up and a dedicated policy team are instrumental in developing such policies. In the case of Bangladesh, the Government has enacted policies including the National ICT Policy 2018, the National Telecommunication Policy 2018 and the Software and Hardware Quality Testing and Certification Policy 2020, which will all assist in developing the digital infrastructure. Bangladesh also has national strategies for key frontier technologies such as artificial intelligence, blockchain, robotics, the Internet of things, and microprocessor design capacity, which can all help build a vibrant, digitized STI ecosystem in the country. At the other end of the spectrum, some least developed countries (such as Kiribati and Madagascar) do not yet have an STI policy or plan.

> **It is worth noting that a third of existing plans in the least developed countries have section(s) dedicated to gender equality and another third mentioned gender equality within their plans. Half have section(s) dedicated to environmental sustainability, which shows that least developed countries' Governments recognize the importance of STI to solve this important development challenge.**

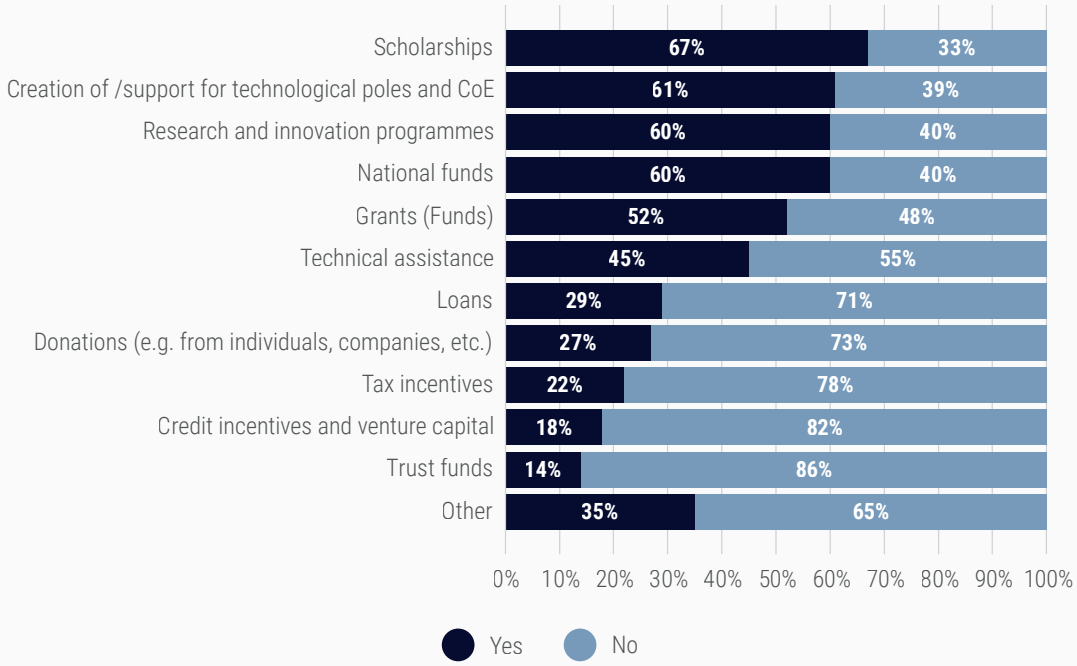
The existence of regulatory frameworks and policies helps improve coordination among actors at the national level, and almost half of the least developed countries have a national legal framework.

National laws have been used to provide a legal framework for research and (higher) education (i.e. Bangladesh, Benin, Burkina Faso, Democratic Republic of the Congo, Senegal). National decrees have been enacted to create specific STI authorities or national research centres (i.e. Benin, Burundi, Senegal), to approve or adopt national policies, and to finance or regulate IT equipment (i.e. the Comoros), cybersecurity (i.e. Madagascar), the organization of research in different application areas (i.e. Senegal and Togo) or diploma recognition (i.e. Senegal). In nearly half of the least developed countries, STI-related national law(s) have been adopted. For instance, Malawi and Zambia have dedicated legal acts for their national science and technology framework, and Bangladesh and the Comoros for their ICT/digital communication framework.

Intellectual property rights are a major issue for the least developed countries. While technologies from developed countries benefit from intellectual property protection (patents, trademarks and copyrights), intellectual property protection systems in the least developed countries are either not in place or are very weak and not enforced. Without a patent system, firms in emerging economies have less incentive to develop and commercialize innovations. Countries need to find a balance between encouraging follow-up innovation by competitors and granting intellectual property protection for innovations within the least developed countries. Stringent intellectual property protection can limit the use of globally relevant frontier technologies that could be very beneficial in sectors such as agriculture, health and energy in the least developed countries. There are thus many incentives for the least developed countries to adopt open-source science and technologies, as they are driven by autonomy and independence from proprietary technologies or software, a desire to address intellectual property rights enforcement, a need to reduce costs and a growing concern for accountability or transparency of public sector governance.

Scholarship programmes that target the pressing need to build human capital (e.g. Chevening or the Commonwealth Scholarships) are a common operational policy instrument in the least developed countries. Other instruments support the creation and development of technological institutions and centres of excellence, which are usually located within universities. For instance, pan-African networks are thriving, such as the World Bank-funded African Centres of Excellence in West and East Africa or the African Institute for Mathematical Sciences (AIMS). Relating to the research and innovation programmes, the United Republic of Tanzania's Funguo Programme is a good example of a catalytic fund that addresses both innovation-ecosystem capacities and building the enabling environment. National funds are also set up, for instance in Bangladesh (notably innovation and business entrepreneurship funds) and in Benin (sectoral funds in agriculture, environment and climate).

Figure 13. Types of applicable operation policy instruments



Source: Technology Bank survey 2021.
Note: CoE stands for centres of excellence.

The most common funding instrument for innovation is grant schemes, which are also used to support businesses and academic–industry collaboration. For instance, international donors and national authorities in Rwanda and Bangladesh have set up innovation grant programmes/challenges. On the other hand, financial and fiscal instruments such as loans, donations, tax incentives, credit incentives and venture capital as well as trust funds are lagging behind.

Monitoring STI trends, the implementation of policies and plans, and the performance of STI organizations is key to ensuring effectiveness. However, monitoring and evaluation of the STI systems in the least developed countries is currently lacking or very weak, and capacities on STI statistics based on international standards are generally low in these countries, even though two thirds of them have already defined a set of national-level indicators to monitor STI progress.

Box 5. Example of STI indicators used in Bangladesh

- Proportion of individuals using the Internet
- Proportion of population covered by a 2G mobile network
- Proportion of population covered by a 3G mobile network
- R&D expenditure as a percentage of GDP
- Proportion of medium- and high-tech industry value added in total value added
- Proportion of individuals who own a mobile telephone, by sex
- Proportion of total research budget allocated to research in the field of marine technology
- Fixed Internet broadband subscription per 100 inhabitants by speed
- Proportion of youth and adults with ICT skills, by type of skills

Source: Survey analysis (see also https://www.sdg.gov.bd/page/allgoals/4#9)

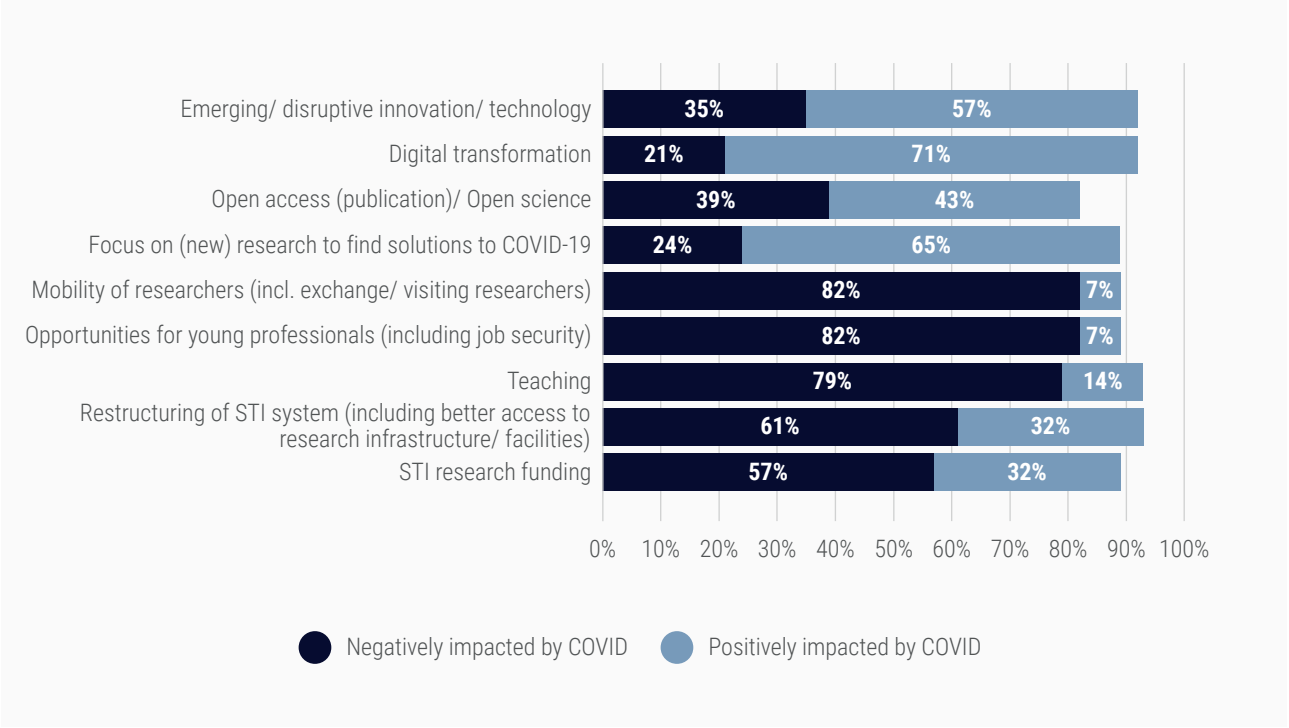
In this context, regional initiatives that are not centred on the least developed countries offer some support. Targeting all African countries, the African Union Development Agency (AUDA-NEPAD) African Science Technology and Innovation Indicators initiative under the Consolidated Plan of Action (CPA) established the African-based systems for collecting and analysing STI indicators and a harmonized platform for publishing STI indicators. Developing STI indicators that are specific to the least developed countries and tracking their progress is an urgent requirement that needs to be centrally coordinated within the United Nations system for these countries.

3.7 Impact of COVID-19 on STI in the least developed countries

The COVID-19 crisis and its associated "great lockdown" have had a heavy toll on least developed countries' economies. Various sectors of the economy have been drastically affected including tourism, fuel export, raw materials and the textile industry. In addition, the flow of remittances to least developed countries has seen a sharp downturn which, together with a soaring trade deficit, means least developed countries are facing tough conditions to foster STI. It has also resulted in a slowdown in research, especially field research. Conferences and peer events have been postponed or taken place online, which is detrimental to scientists in least developed countries who benefit from the knowledge-sharing and network-building that takes place at these international events. It has also likely had a negative impact on innovation due to firms producing less or experiencing higher rates of failure.

However, the impact of the COVID-19 pandemic on STI in the least developed countries has also constituted an opportunity or source of progression in certain STI-related areas (see Figure 14), as some Governments and communities across these countries have successfully used innovative solutions and STI policies to tackle challenges arising from the COVID-19 pandemic.

Figure 14. STI areas impacted by COVID-19



Source: Technology Bank survey 2021.
Note: The results were impacted by the variation in the frequency of responses/total response rate of survey participants.

The majority of least developed countries consider that the COVID-19 pandemic has negatively impacted gains that had been made in STI.[88] Already-scarce funding for STI has been diverted to other priorities such as access to health care (e.g. Democratic Republic of the Congo, The Gambia, Nepal, United Republic of Tanzania, Uganda). Many international partners have revised their commitments in terms of financial and human resources dedicated to STI development. It has also been difficult to pursue scientific collaboration with international counterparts, resulting in several STI projects being put on hold. In the case of Lesotho, food production initiatives declined, and many STI awareness-raising and capacity-building initiatives stopped. Madagascar reported that many innovations ended at the stage of prototypes.

However, Angola, Bangladesh, Burkina Faso, Timor-Leste, Togo and Zambia consider that STI research funding and restructuring of STI have been positively affected during the COVID-19 pandemic. Bangladesh, the Comoros, The Gambia, Malawi and Rwanda indicated that they have advanced their digital transformation, as various technology solutions have been developed for online services (e.g. e-commerce, mobile financial services, e-education, e-governance).

In most least developed countries, Governments provided incentives through research grants for developing STI solutions to tackle COVID-19, for instance the Special Collaborative Research Grant in Rwanda.

In Togo in September 2020, WHO approved a protocol for phase three clinical trials of a herbal medicine solution funded by the Government. In Mozambique and the United Republic of Tanzania, funding was provided for the Ministry of Health and the Ministry of Education to use digital platforms for awareness-raising and prevention measures, as well as teaching online content. Meanwhile, in Bangladesh the Government developed several STI solutions for contact tracing, self-testing, telemedicine, vaccination programmes and innovations (regarding ventilators and other medical equipment). It also encouraged the development of several STI solutions, such as the iLab initiative under the a2i[89] programme that has developed three ventilators for COVID-19 treatment. Currently, the a2i Innovation Fund is contributing to the progressive manufacturing of oxygen concentrators and high-flow nasal cannulas using local technology. Furthermore, the iLab initiative of the a2i programme is also developing a low-cost personal protective equipment safety gown. Finally, government funds allocated to research have contributed to the development of the Bangasafe oro-nasal spray, for which phase three clinical trials are ongoing.

However, Benin, The Gambia, Kiribati, Lao's People's Democratic Republic, Lesotho, Malawi, Timor-Leste, and even Rwanda pointed to the overall lack of government incentives for STI solutions to respond to the COVID-19 crisis. They added that had additional funds been allocated to STI, least developed countries could have responded better to the COVID-19 pandemic.

Investing more in research and innovation – especially in the health sector for vaccine development, disease surveillance and control measures – by ensuring that laboratories have modern IT equipment is considered a priority by least developed countries. Lesotho and Benin suggested establishing a special research programme on the use of traditional medical plants as alternative treatments. This would encourage the emergence of innovation from national ecosystems using indigenous knowledge.

In least developed countries, diffusion of locally developed innovations is lagging at the national level and with other countries. For example, Rwandan scientists developed novel models of pool testing by combining individual samples in a single tube and using molecular biology detection methods to test them all at once. If the pool is positive, individual patients are tested. This method saves both time and financial and human resources. However, so far, the innovation has not been widely shared with other least developed countries. Meanwhile, The Gambia, Mozambique and Niger said that more efforts could have been made to use STI efficiently for awareness-raising activities and to teach communities the appropriate sanitary measures to avoid the spread of the disease. In The Gambia, for instance, there is a high level of misinformation among the public that has significantly affected the perception of, and attitudes towards, COVID-19. There is also a gender gap where misinformation about the vaccines has led to a low vaccine roll-out among women, many of whom worry it may impact their ability to bear children.[90]

88 Technology Bank survey 2021.
89 The a2i programme is the flagship programme of the Digital Bangladesh agenda to inspire developing and developed nations regarding public service innovation and transformation by sharing groundbreaking insights supported by examples, lessons and knowledge. For more information, see https://a2i.gov.bd/.
90 See, for example, https://www.africanews.com/2021/10/14/vaccine-misinformation-blamed-for-low-turnout-among-gambian-women/.

3.8 The business case for STI

The long-term business case for investment in STI is clear. Long-term productivity upgrading, economic development and job creation, as well as addressing societal challenges, are all dependent on sustainable and strong STI systems. However, the gap between current investment levels and policy targets, let alone long-term optimal levels, clearly highlights a significant funding gap across the board. Nevertheless, for the least developed countries – and to some extent also for donors and funders – investing in STI may seem less urgent than more tangible pressing challenges, including health care, primary education and security. How can the business case for STI be strengthened? What would be the priorities of such investment? This section will summarize the high-level report's findings on these important questions.

A key perspective: human capital and absorptive capacity as immediate return

One of the main reasons why investment in STI pays off not just decades later, but right from the start, is that it directly builds critical human capital. Although the prototypical impacts of science and R&D/innovation can either take a very long time (delay between published frontier research after starting a PhD) or be very rare and uncertain (a start-up unicorn from an innovation fund), it is important to recognize that in the process, highly valuable human capital and absorptive capacity are created. Many PhD students or scientists join industry or the Government, where they promote new knowledge and the uptake of new ideas. Meanwhile, better-trained scientists can ensure that tertiary education quality is upgraded to offer students updated insights from science, which they can subsequently apply in their work.

Even when R&D has no concrete innovation success, it teaches companies which technologies are relevant and which are useful. In fact, it is now commonly recognized that firms do not just engage in R&D for innovation purposes, but also to be able to engage with the outside world, thereby raising their absorptive capacity.[91]

Given that human capital is the key mediating factor of STI development, aspects of inclusion, including gender equality, are evidently important to integrate and address. When human capital is critical, no country can afford to overlook half of its population (see Box 6); women constitute a target group of strategic importance. Indeed, to realize its potential, society must be able to access its various segments, including women – whose participation in the knowledge economy in the least developed countries is still lagging behind. Consulting and working with women in the choice, development and application of technologies in a variety of sectors will help foster their participation at all levels of STI education and in the private and public workforce (women in science) and in developing and implementing science and technology approaches that benefit women (science for women). Ensuring that they have access to sufficient resources to take advantage of and benefit from science and technology innovations is also crucial.

Several initiatives can be highlighted, such as the Organization for Women in Science for the Developing World (OWSD), a programme unit of UNESCO. OWSD is the first international forum to unite eminent women scientists from developing and developed countries with the objective of strengthening their role and promoting their representation in scientific and technological leadership. OWSD provides grants to women scientists from the least developed countries to undertake research in engineering and information technology sciences.

91 Wesley M. Cohen and Daniel A. Levinthal, "Innovation and learning: the two faces of R & D", *The Economic Journal*, vol. 99, No. 397 (September 1989).

Box 6. Focus: gender gap in STI in the least developed countries

Women have a stake in participating in the digital economy to ensure that the Fourth Industrial Revolution does not perpetuate the gender bias. Women are disproportionally affected by barriers that limit their mobile technology access, use and deployment. These include factors such as low literacy rates, low mobile phone ownership, inability to afford a mobile phone or mobile data, low digital skills as well as safety and security concerns. In some specific situations, women need the consent of their families to own a mobile phone. Furthermore, in poor families, a single mobile phone might be shared by several family members.

In some countries, such as Bangladesh and Ethiopia, men are twice as likely as women to have access to mobile technology. Furthermore, the evidence available suggests that women will lose five jobs for every one gained through the Fourth Industrial Revolution, compared with the loss of three jobs by men for every one gained. Most children entering primary school today might end up working in jobs that do not yet exist. Less than 2 per cent of girls have plans to become an engineer. Despite a shortage of skills in technological fields that are driving the Fourth Industrial Revolution, women still account for only 28 per cent of engineering graduates and 40 per cent of graduates in computer science and informatics.

Access to finance is another major obstacle for women. Start-ups are very often considered a risky investment and banks are reluctant to finance them, with access to finance being the most common barrier to starting a new business. This is even more acute for businesses owned by women, who often lack financial guarantees, as their home may be registered in their husband's name for instance. In Africa, a growing number of Governments have come to recognize the importance of providing flexible finance, particularly for women wanting to start a business.

Leveraging frugal and innovative investment solutions

Building on the insights from the earlier sections, the least developed countries can be characterized by their frugal science systems, meaning they achieve results using limited means. This approach mainly involves effective international collaboration (for instance working with diaspora), working with frugal scientific methods (see Box 7 on the use of citizen science), as well as the dedication and drive of individual scientists. While these frugal states themselves are not desirable, the positive aspects such as a drive for collaboration and a focus on value-for-money can be leveraged in a positive way for future STI development. Investment in collaboration with international partners can result in substantial leverage of limited domestic funds. Furthermore, positioning countries as high "value-for-money" science and R&D producers may attract international investment, be it private or public. Of course, a precondition is to have sufficiently high-quality performance.

Box 7. Citizen science

The general population can be considered an emerging group targeted by STI initiatives funded in the least developed countries. These end users can learn, test and adapt new technologies, altering the tools that STI offers to support their needs. Progress towards achieving the SDGs can be achieved only if innovation and technological advancement can reach and benefit broader local communities.

For instance, 14 countries are benefiting from a partnership forged in 2020 to harness satellite technology to tackle food insecurity resulting from the COVID-19 crisis: the CropWatch Innovative Cooperation Programme under ESCAP, UNCTAD-United Nations Commission on Science and Technology for Development (-UNCSTD), the Alliance of International Science Organizations (ANSO) and the Aerospace Information Research Institute (AIR) of the Chinese Academy of Sciences (CAS). In Mauritania, the Food and Agriculture Organization of the United Nations (FAO) launched several programmes aiming to enhance the population's resilience to the impacts of the COVID-19 pandemic through the introduction of innovative practices, including digital innovations and innovative watershed management approaches. Meanwhile, the Aspire to Innovate (a2i) programme in Bangladesh funded by the United Nations Development Programme (UNDP) is also citizen-centred.

4. An engaged regional and international community for STI development in the least developed countries

In many of the least developed countries, international donors are driving the STI agenda, and bring much of the funding for STI to the table. They focus on capacity-building and skills development, diffusing STI knowledge and boosting international collaborations, fostering collective STI actions towards the SDGs and addressing the needs of all stakeholders participating in STI, named the "quadruple helix" in a relationship described below. Some donors have addressed key features of the least developed countries' innovation systems, such as indigenous knowledge and the importance of regional integration for STI. While historically official development aid for STI in least developed countries was in a form of grants, an alternative trend towards innovative financing has been seen in recent years.

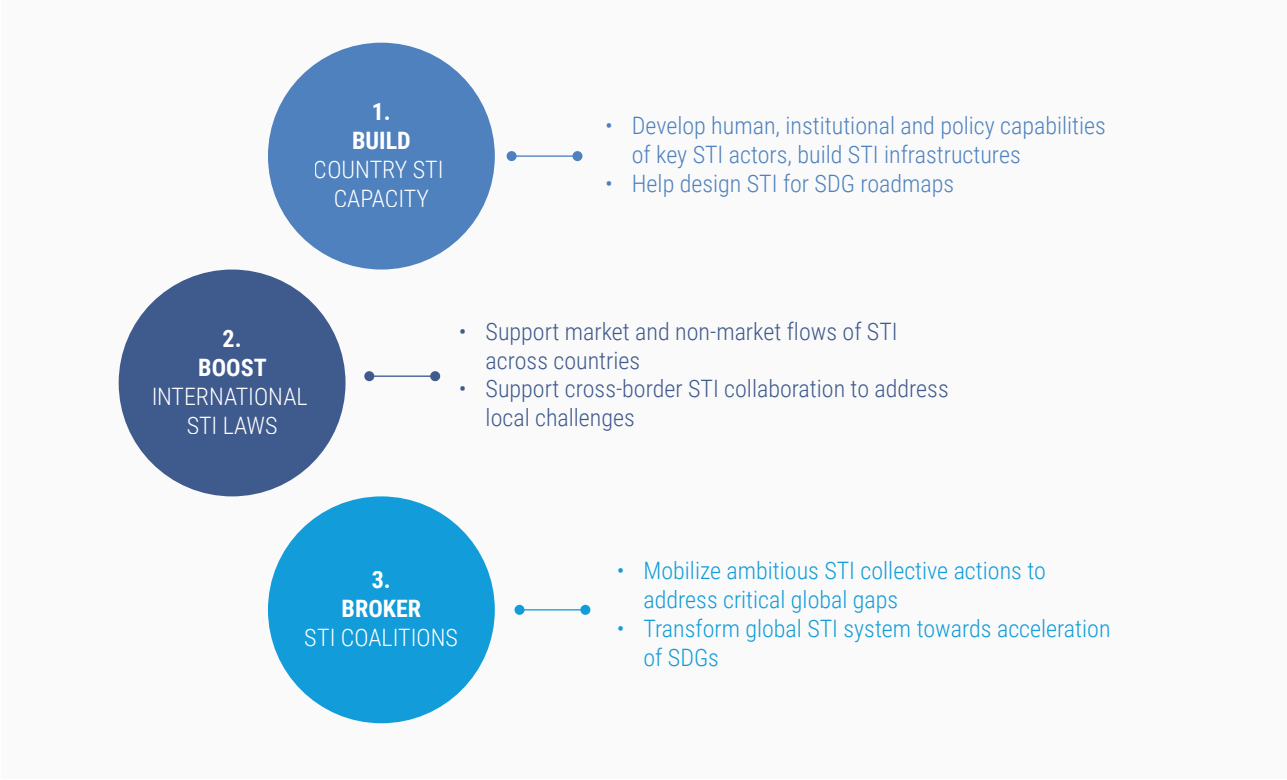
It has now been a decade since innovation first emerged as a concept alongside science and technology in the discourse of development.[92] A parallel process occurred in the agendas of policymakers in least developed countries, often under the impulse of international organizations, in a more or less coordinated manner. Numerous are the international actors (OECD, UNCTAD, the United Nations Economic and Social Commission for Asia and the Pacific [UNESCAP], UNESCO, the World Economic Forum), bilateral organizations (Agence Française de Développement, Department for International Development, Deutsche Gesellschaft für Internationale Zusammenarbeit, Global Affairs Canada and International Development Research Centre), regional organizations (African Regional Economic Communities; AUDA-NEPAD; ASEAN; Directorate-General for Research and Innovation; Indian Ocean Commission; Organisation of African, Caribbean and Pacific States; Pacific Island Forum), multilateral development banks (African Bank for Development [AfDB], Asian Development Bank, European Investment Bank, Inter-American Development Bank, the World Bank) and international STI-related institutions (African Observatory of Science, Technology and Innovation, African Academy of Sciences, World Academy of Sciences) that have invested in the field.

Figure 15. Mapping of international organizations supporting STI in least developed countries

92 Bengt-Åke Lundvall, *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning* (London, Pinter, 1992).

These organizations have focused so far on building the STI capacities of least developed countries, developing the human, institutional and policy capabilities of key STI actors and building STI infrastructures. They have also engaged in the design of the STI components of the SDG roadmaps; addressed the market and non-market flows of STI; supported cross-border collaborations; and fostered the crucial need for collaborations among STI actors, in the quadruple helix of the public sector, academia, private sector and citizens. More recently, these lines of interventions have been formalized in the context of addressing the sustainable development challenges (see Figure 16).

Figure 16. Pillars for STI collaboration for the SDGs



Source: Guidebook for the Preparation of Science, Technology and Innovation (STI) for the Sustainable Development Goal Roadmaps.

4.1 Capacity-building and skills development

Developing the human, institutional and policy capabilities of key STI actors (the private sector, academia and Government) and building STI infrastructure, are among the main pillars of the intervention of international donors.

Several development actors have funded STI initiatives to enhance the skills of private sector actors and contribute to the development of an entrepreneurial culture in least developed countries, encouraging openness and innovation.[93] Notably, the ITU has a special programme for the least developed countries, providing both technical expertise and financial assistance across all ICT-related activities, including in the areas of market regulatory reforms and ICT infrastructure. Furthermore, the Fast-Track Africa Initiative funded by the International Trade Centre supports digital entrepreneurs and start-ups in five least developed countries (Benin, Ethiopia, Mali, Rwanda, and Zambia) with online and on-site training, advice and coaching focused on building digital and online skills. According to the 2020 report, a total of 1,063 digital entrepreneurs and start-up founders were trained, including 296 women and 695 youth. Six tech hubs were strengthened through capacity-building,

93 UNCTAD, *The Least Developed Countries Report 2020: Productive Capacities for the New Decade* (New York, United Nations publication, 2020).

and over US$800,000 of investments were raised.[94] In the Asia-Pacific region, initiatives funded by the World Bank and bilateral donors support challenge funds for collaborative research and innovation, as well as the creation of incubator spaces and programmes.

Human resources development for STI through secondary and tertiary education, as well as technical and vocational training institutions, are also supported by international development partners such as the World Bank and bilateral donors, targeting both students and institutions.

The reinforcement of local government actors is also key. Good governance is increasingly recognized as a key ingredient for achieving development, and is highlighted by the report of the Secretary-General on the implementation of the Programme of Action for the Least Developed Countries for the Decade 2011–2020.[95] A sound regulatory environment can protect entrepreneurs and investors, encouraging them to take risks. Several initiatives funded by international actors focus on capacity-building and the skills development of government actors.[96] For instance, the WIPO-Swedish International Development Cooperation Agency (SIDA) Advanced International Training Program is a key initiative on intellectual property for least developed countries, providing technological capacity-building and cooperation to encourage invention, innovation and creativity in least developed countries. This programme is organized by WIPO in cooperation with the Swedish Intellectual Property Office and SIDA. Senior officials and policymakers dealing with various aspects of intellectual property at national and community levels from 14 least developed countries were invited to attend training.[97]

Some NGOs, as well as the International Development Research Centre, also play a central role, such as the African Academy of Science through the Alliance for Accelerating Excellence in Science in Africa platform. In Asia, UNESCAP is supporting the design of STI policies and roadmaps, for instance in Cambodia and Myanmar. Globelics networks, supported by SIDA, aim at creating a pool of innovation policy researchers and experts to support STI development and foster cross-country collaborations.

4.2 Diffusing STI knowledge in least developed countries and boosting cross-country collaborations

Dissemination of relevant research and information through networks, advisory centres, specialist libraries and databases enhance STI knowledge across the least developed countries.

A large-scale initiative is Research4Life, a public-private partnership between United Nations organizations (FAO, International Labour Organization, United Nations Environmental Programme [UNEP], WHO and WIPO), Cornell University, Yale University and 180 publishers. It provides institutions in over 125 low- and middle-income countries with online access to up to 111,000 books and 29,000 journals. It aims to improve teaching, research and policymaking in health, agricultural, environmental and other life, physical and social sciences.[98] Indeed, key stakeholders and researchers are now sharing their data and research results across platforms, so that the global scientific community, including from least developed countries, can utilize this knowledge and further build upon it.[99]

Among the main stakeholders identified, the United Nations Economic Commission for Africa (UNECA) conducts research on national and regional innovation systems, technology transfer, and new and emerging technology likely to support economic transformation, and in key areas such as agriculture and social service delivery, where innovations and new technologies can support economic transformation and human resource development.

Furthermore, UNESCO has launched the Global Observatory of Science, Technology and Innovation Policy Instruments. This online, open access platform for decision makers, researchers and the public, is intended

94 International Trade Centre, *#FastTrackTech Africa Annual Report 2020* (2020).
95 United Nations, A/76/71–E/2021/13
96 Observations based on the matrix "Mapping of STI stakeholders and initiatives in LDCs".
97 Representatives from Bangladesh, Bhutan, Cambodia, Ethiopia, Lao People's Democratic Republic, Malawi, Mozambique, Myanmar, Nepal, Rwanda, Sudan, Tanzania, Uganda and Zambia attended the training held in June 2021. A follow-up meeting was planned for December 2021.
98 Users can access content through five programmes: Access to Global Online Research in Agriculture (AGORA), Access to Research for Development and Innovation (ARDI), Global Online Access to Legal Information (GOALI), Health InterNetwork Access to Research Initiative (HINARI) and Online Access to Research in the Environment (OARE). See https://www.research4life.org/about/.
99 UNESCO, *UNESCO Science Report: Towards 2030*, 2nd ed. (Paris, 2016).

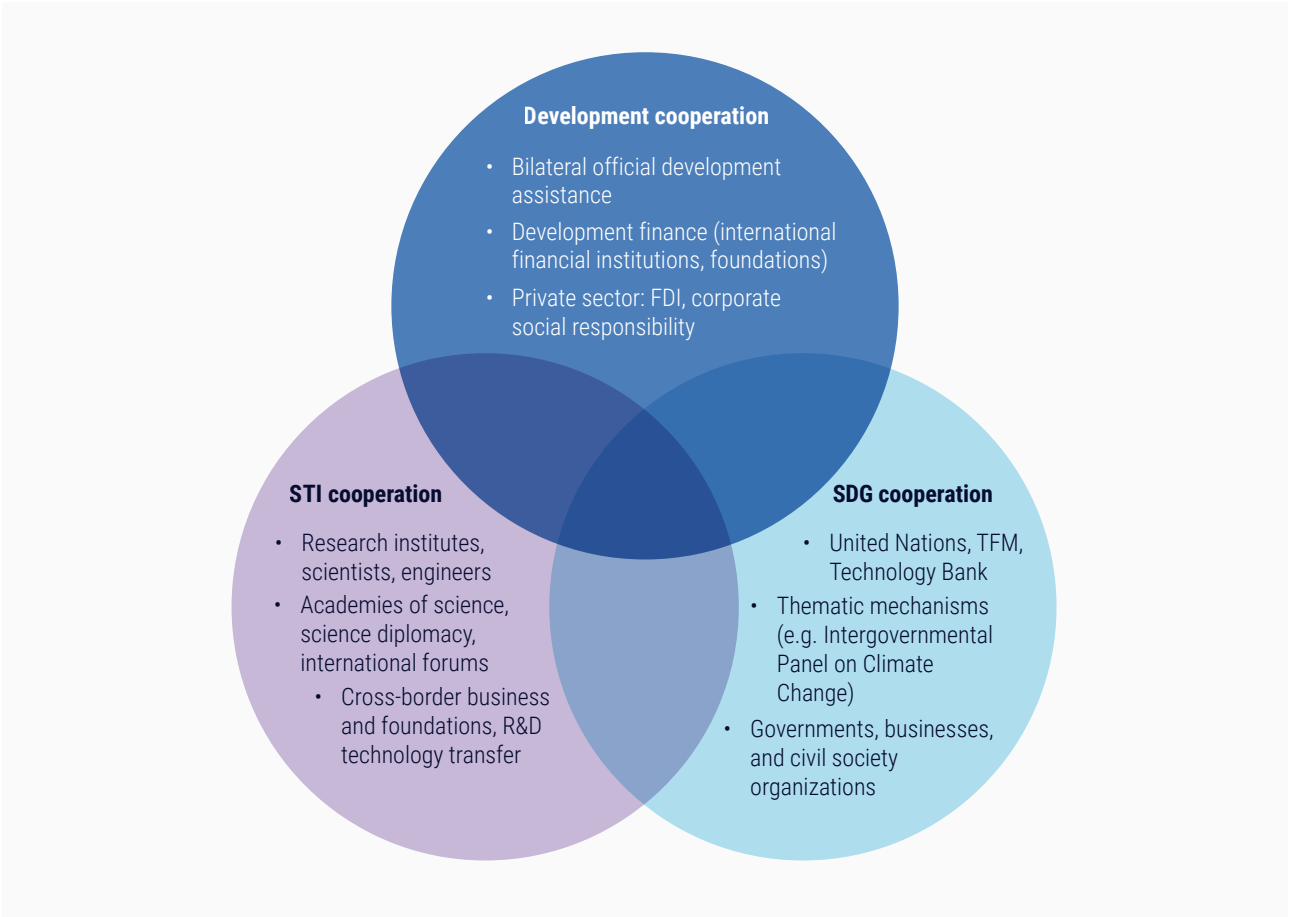
to provide key information on STI governing bodies, legal frameworks and policy instruments.

AUDA-NEPAD, in collaboration with the African Union Commission, African Union Member States and other partners, has implemented the African Science, Technology and Innovation Indicators Initiative since 2007. The activities which have been carried out include strengthening the capacity of survey teams at national level, monitoring development and innovation surveys in 43 countries, supporting the analyses of survey data, and the publication of the *African Innovation Outlook* report. The third *African Innovation Outlook* was published in 2020, presenting the status of R&D and innovation performance in Africa, focusing on the period 2013–2016.[100] This publication enables an understanding and monitoring of the data on STI indicators, of particular importance as it demonstrates the progress made by African countries, 33 of the 46 least developed countries, on STI goals.

4.3 Fostering collective STI actions towards the SDGs

Since the adoption of the 2030 Agenda for Sustainable Development by the United Nations in September 2015, and the launch of the TFM, STI initiatives funded by United Nations organizations, multilateral development banks, bilateral organizations, NGOs and foundations in the least developed countries have focused on the achievement of the SDGs. Figure 17 shows the different domains and actors in international STI that interact in pursuit of the SDGs. While there is a tendency towards greater cooperation, their efforts can be considered as fragmented to some extent, as donors do not much use the existing coordination forums.

Figure 17. International cooperation on STI for the SDGs: domains and actors



Source: Guidebook for the Preparation of Science, Technology and Innovation (STI) for the Sustainable Development Goal Roadmaps.

100 AUDA-NEPAD, *African Innovation Outlook 2019* (Johannesburg, 2019).

Challenges posed by climate change are especially pressing for least developed countries and Small Island Developing States. Some STI initiatives address climate change and environmental protection, highlighted by SDG 7, Affordable and Clean Energy, and SDG 13, Climate Action. For instance, through the UNEP DTU Partnership, UNEP provides research-based advisory services to assist developing countries and least developed countries to deliver on the Paris Agreement and the SDGs. UNEP works closely with institutional actors to promote climate planning and policy, transparency and accountability, as well as market development.

Another example is the least developed countries' Universities Consortium on Climate Change, a South-South long-term capacity-building platform comprising 10 universities,[101] which allows universities, faculty members and students to share experiences and knowledge on climate change and build capacity through education, training, research and communication. The ITU also has a special programme for least developed countries, providing both technical expertise and financial assistance in the field of climate adaptation and disaster response. In the future, the least developed countries can improve their development outcomes in this regard through leveraging the potential of ICT/broadband and telecommunication services.

Concerning collaboration and knowledge transfer, several platforms for collaboration have been initiated. These includes UNEP's Climate Technology Centre and Network, which accelerates the transfer of climate technologies through technical assistance and providing access to information.[102]

Furthermore, several actors provide access to finance for start-ups and MSMEs from the energy and environment sectors. This includes for instance Boost Africa financed by the European Investment Bank and the African Union, or the Digital Energy Facility financed by the French Development Agency (AFD) and aimed at supporting the digitization and modernization of the energy sector in Africa.

In the last two years, the international development community has also mobilized to fund initiatives to help least developed countries address the impact of the sanitary crisis. Several international organizations, especially United Nations organizations, have created platforms for cooperation.

The Access to COVID-19 Tools Accelerator is the world's most comprehensive end-to-end solution to ending the acute phase of the COVID-19 pandemic. It brings together Governments, health organizations, scientists, businesses, civil society and philanthropists to accelerate the development and production of, and equitable access to, COVID-19 tests, treatments and vaccines. It was launched by WHO, European Commission, France, and the Bill & Melinda Gates Foundation in April 2020.[103]

The Tech Access Partnership was launched by the Technology Bank, in collaboration with UNDP, UNCTAD and WHO in 2020 and is led by the Technology Bank as part of a coordinated approach to strengthening developing countries' responses to COVID-19 and increasing access to health technologies. The Tech Access Partnership's key functions include product information, technical guidance, and facilitating partnerships through a platform to match companies based on expertise, needs and capacity.

UNECA has also developed the Africa UN Knowledge Hub for COVID-19, a one-stop-shop on information on the pandemic and resources relevant to Africa. The Hub harnesses information and resources from credible sources including WHO, regional United Nations organizations, and the ministries of health of African Governments.

In the Asia-Pacific region, the Asian Development Bank and the South Asian Association for Regional Cooperation (SAARC) have provided financial assistance packages. The Asian Development Bank's COVID-19 Response is a US$20 billion package to support its developing member states, with US$2 billion earmarked for the private sector.[104] The SAAC's COVID-19 Emergency Fund of US$21.8 million has raised proportionate contributions from every member state.[105]

Overall, there is a trend towards multilateral collaboration, whereby multiple actors work together and try to utilize innovative funding instruments to counterbalance global protectionism and competition. Multilateral

101 See http://www.icccad.net/luccc/.
102 See https://www.ctc-n.org/.
103 See https://www.who.int/initiatives/act-accelerator.
104 See https://www.adb.org/what-we-do/covid19-coronavirus.
105 United Nations COVID-19 Response and Recovery Fund, *The Secretary-General's UN COVID-19 Response and Recovery Fund* (2020). Available at https://unsdg.un.org/sites/default/files/2021-01/COVID19-Response-Recovery-Fund-Document_2.pdf.

collaboration offers the opportunity to scale innovation beyond the initial concept phase by spreading risk among stakeholders and pooling resources and expertise. A good example is Gavi, the Vaccine Alliance. By gathering all the key actors in the field, namely the Bill & Melinda Gates Foundation, the United Nations Children's Fund (UNICEF), WHO, the World Bank, pharmaceutical industries, Governments from donor and developing countries, and international organizations into one decision-making body, Gavi concentrated efforts on closing critical gaps in the provision of vaccines.[106] Since its creation in 2000, Gavi has helped vaccinate more than 822 million children in the world's poorest countries, preventing more than 14 million future deaths.[107] Gavi is co-leading the COVID-19 Vaccines Global Access or COVAX, the vaccines pillar of the Access to COVID-19 Tools Accelerator. However, it has fallen short of its forecast deliveries: of the 640 million doses it initially planned to make available by August 2021, only 236 million were delivered.[108] This is partly due to competition between developed countries to secure their own vaccine delivery, and partly due to difficulty in closing deals with major vaccine manufacturers.[109]

Other local actors can also play a key role in the COVID-19 response and should be reinforced, such as the team set up by the African Union for the procurement of vaccines for the continent. The African Union, through the Africa Centres for Disease Control and Prevention, has worked with the African Vaccine Acquisition Trust to secure thousands of doses.[110]

The Global Initiative on Sharing Avian Influenza Data (GISAID) platform launched in 2008, an alternative to public domain archives which aims to provide open access to the genomic data of influenza viruses and, more recently, COVID-19.[111] Unlike traditional public domain archives, GISAID users must agree to a data access agreement that governs the way data can be used, which promotes the acknowledgement of data generators, collaboration and using data for common social good. GISAID has been recognized for incentivizing the rapid exchange of outbreak data during influenza pandemics and the COVID-19 pandemic. After releasing the first complete genome sequences of the SARS-CoV-2 virus, GISAID's database reached over 2.4 million submissions from researchers in over 170 different countries in just six months.

Another example is the COVID-19 data portals, developed by a task force from the European Molecular Biology Laboratory's European Bioinformatics Institute with the wider scientific community. It is the primary entry point for the European COVID-19 Data Platform, which enables the rapid collection and comprehensive data-sharing of available research data from different sources among global research communities. The national COVID-19 data portals provide information, guidelines, tools and services to support researchers in creating and sharing research data on COVID-19. The purpose of the national data portals is to showcase and highlight COVID-19 research data from each of the participating countries. Since its launch, the Data Platform has had 4.4 million web requests, over 180,000 users and 1,500,000 views of records.[112] Over 300 institutions from 30 countries have deposited data. The platform has driven the release of 85 per cent of global viral raw sequence data into the public domain.

According to an OECD research paper, innovation from low-income countries did not receive much attention or support from the international development and humanitarian communities.[113] Instead of providing support to local innovation, international actors funded their own innovations and tools in least developed countries. Their interests are often disconnected from those of the main target beneficiaries.[114] This disparity has been progressively more acknowledged by a broad

106 UNESCAP, *Science, Technology and Innovation for Sustainable Development in Asia and the Pacific: Policy Approaches for Least Developed Countries* (Bangkok, United Nations publication, 2016).
107 See https://www.gavi.org/.
108 Benjamin Mueller, "Where Covax, the vast global vaccine program, went wrong", *New York Times*, 2 August 2021. Available at https://www.nytimes.com/2021/08/02/world/europe/covax-covid-vaccine-problems-africa.html (accessed on 15 December 2021).
109 Magali Chelpi-den Hamer, "Covax: faut-il continuer à financer un échec?", Institut de Relations Internationales et Stratégiques, 30 August 2021. Available at https://www.iris-france.org/159808-covax-faut-il-continuer-a-financer-un-echec/ (accessed on 15 December 2021).
110 African Union, "African Vaccine Acquisition Trust delivers 12 000 doses of COVID-19 vaccine to the African Union", 3 September 2021. Available at https://au.int/en/newsevents/20210903/african-vaccine-acquisition-trust-delivers-12-000-doses-covid-19-vaccine-african (accessed 15 December 2021).
111 See https://www.gisaid.org/.
112 See https://www.covid19dataportal.org/.
113 Ben Ramalingam and Benjamin Kumpf, "COVID-19 innovation in low and middle-income countries: lessons for development co-operation", OECD Development Policy Papers, No. 39 (Paris, OECD Publishing, 2021).
114 UNCTAD, *Achieving the Sustainable Development Goals in the Least Developed Countries: A Compendium of Policy Options* (New York and Geneva, United Nations publication, 2018).

range of actors, including in the OECD Development Assistance Committee's peer learning exercise on innovation for development, in the WIPO's Global Innovation Index 2020, and by WHO. More efforts are now directed towards diversifying STI initiatives, by including providing greater support for mission-driven transformative innovation and bottom-up local innovations. This may lead to a more rebalanced model with increased participation and ownership by actors in low-income countries and least developed countries.[115]

4.4 Addressing the needs of stakeholders and the quadruple helix

Initiatives target the quadruple helix of the Government and public actors, academia, the private sector and citizens. It takes the involvement of them all to produce STI adequate to meeting the development challenges faced by the least developed countries.

Several initiatives address exclusively the private sector and provide support mainly to MSMEs and start-ups through access to early-stage funding, such as the Innovation Accelerator launched by the World Food Programme and the Africa Technology Ventures funded by the European Investment Bank. The funding provided is reinforced by capacity-building initiatives and technical assistance to enable the private sector to develop the right skills to grow and identify business opportunities, such as the #FastTrackTech Africa initiative funded by the International Trade Centre. This initiative supported 2,000 digital entrepreneurs and 200 tech start-ups in sub-Saharan Africa (Benin, Côte d'Ivoire, Ethiopia, Rwanda, the United Republic of Tanzania, and Zambia) go international, with online and on-site training, advice and coaching focused on building digital and business skills. Some other actors propose platforms to create networks, ensure the exchange of good practices, and disseminate research findings and policy recommendations. The evidence produced is of interest not only to the private sector, but also across government and public bodies, international development and research communities, NGOs, and the general population. The United Nations Industrial Development Organization, for instance, has created a technical cooperation programme with a focus on STI which acts as a global forum.

Other initiatives address primarily Governments. Particularly in least developed countries today, Governments struggle to find the human and financial resources to invest in the future when their populations require services. United Nations organizations are the primary actors focusing their initiatives on Governments and public actors. Several initiatives funded by the United Nations focus on least developed countries. WIPO aims at assisting least developed countries to use intellectual property in support of innovation and creativity to address development challenges. UN-OHRLLS, through the network of National Focal Points, engages directly with government representatives from least developed countries to ensure coherence between global discussions and national development priorities.[116] Several NGOs and foundations focus on reinforcing the institutional capacities in the health sector, such as the Bill & Melinda Gates Foundation and the Mérieux Foundation, which intervene primarily in sub-Saharan Africa. Initiatives that target actors from the public and the private sector, commonly known as public-private partnerships, whereby public authorities allow private companies to devise innovative solutions for delivering public services, have recently been increasing in number and scope.

Regarding support for research and education systems, women constitute a target group of strategic importance, since their participation in the knowledge economy in least developed countries is still lagging behind. Consulting and working with women in the choice, development and application of technologies in a variety of sectors will contribute to promoting women's participation at all levels of STI education and in the private and public workforce (women in science), and developing and implementing scientific and technological approaches which benefit women (science for women).[117] It is also necessary to ensure that women have access to sufficient resources to take advantage of and benefit from STI. Hence, many STI programmes specifically target women to help bridge the gender gap.[118] STI policies can support women and their empowerment by formulating initiatives in favour of women in science (women as producers of technology) and of science for women (women as users of technology). In 2021, gender-specific support is more urgent than ever, as the economic downturn caused by the COVID-19 crisis is putting women at even greater risk of poverty

115 UNESCAP, *Science, Technology and Innovation for Sustainable Development in Asia and the Pacific: Policy Approaches for Least Developed Countries* (Bangkok, United Nations publication, 2016).
116 See https://www.un.org/ohrlls/content/ldcs-national-focal-points.
117 UNESCO, *To Be Smart, the Digital Revolution Will Need to Be inclusive: Excerpt from the UNESCO Science Report* (Paris, 2021).
118 UNCTAD, *The Least Developed Countries Report 2020: Productive Capacities for the New Decade* (New York, United Nations publications, 2020).

and exclusion. Indeed, women are overrepresented in vulnerable groups such as informal and part-time workers, and in the sectors most heavily hit by the economic decline in the world, and even more acutely in least developed countries.

Finally, the general population, as end users of STI, is an emerging group targeted by STI initiatives funded in least developed countries. They can learn, test, and adapt new technologies, altering the tools that STI offer to support their needs. Progress towards achieving the SDGs can be achieved only if innovation and technological advancement can reach and benefit broader local communities. For instance, 14 countries are benefiting from a partnership forged in 2020 to harness satellite technology in tackling food insecurity resulting from the COVID-19 crisis: the CropWatch Innovation Cooperation Programme under UNESCAP, UNCTAD-UNCSTD, the Alliance of International Science Organizations,[119] and the Aerospace Information Research Institute of the Chinese Academy of Sciences.[120] In Mauritania, the FAO launched several programmes aiming to enhance the population's resilience to the impacts of the COVID-19 through the introduction of innovative practices, including digital innovations and innovative watershed management approaches. The Aspire to Innovate programme in Bangladesh, funded by UNDP, is also citizen-centred and a good example of recent quadruple helix funding initiatives.[121]

4.5 Unique features of the least developed countries' innovation systems

Indigenous knowledge

International organizations, such as WIPO, provide support to indigenous and other vulnerable communities to ensure that such knowledge is protected. For example in Bhutan in 2017, the National Biodiversity Centre documented traditional knowledge in the country, in partnership with UNDP Bhutan and financed by the Nagoya Protocol Implementation Fund and the Global Environment Facility.

As part of the Global Challenges and Partnerships Sector, the Traditional Knowledge Division carries out WIPO's work on the intersection of intellectual property, traditional knowledge and traditional cultural expressions.[122] Furthermore, the WIPO-SIDA Advanced International Training Programme on intellectual property for least developed countries organizes workshops on intellectual property for building national knowledge while including indigenous efforts to foster invention, innovation and creativity. These capacity-building sessions aimed at public bodies, as support for Governments, ensure that policy agendas include local and native communities. Furthermore, one of the four strategic objectives of STISA-2024 adopted by the African Union is to protect knowledge production, including inventions and indigenous knowledge, by strengthening intellectual property rights and regulatory regimes at all levels in African countries. The STISA-2024 also identifies civil society organizations and think thanks as key advocates, championing the use of indigenous knowledge. No data could be identified on initiatives on indigenous culture in the Asia-Pacific region.

Regional integration

Regional collaboration is important for least developed countries, enabling them to develop their STI ecosystems jointly. On the African continent, Regional Economic Communities have their own STI protocols and programmes, and the East African Community and the Southern African Development Community have offices dedicated to STI issues. The Southern African Development Community adopted a Protocol on STI,[123] signed by heads of member states in 2008. The objective of the protocol is to foster regional cooperation and promote the development and harmonization of STI policies. The East African Community established the East African Science and Technology Commission in 2015, which seeks to promote and coordinate the development, management and application of STI in the member states.[124] The East African Community has entrusted the Inter-University for East Africa with the

119 See http://www.anso.org.cn/.
120 See http://english.aircas.ac.cn/; https://english.cas.cn/.
121 See https://a2i.gov.bd/.
122 See https://www.wipo.int/about-wipo/en/activities_by_unit/index.jsp?id=122.
123 Southern African Development Community, *Protocol on Science, Technology and Innovation* (2008). A tender to evaluate and monitor the framework for the protocol was launched in 2019, but at the time of writing no data were available.
124 See https://easteco.org/historical-background/.

mission of developing a Common Higher Education Area, contributing to a greater scientific mobility and knowledge-sharing in the region.[125] These Regional Economic Communities provide platforms for exchange of knowledge and good practices, as well as institutional capacity-building between member states. Regional cooperation in STI enables African countries to pool their scarce resources, including R&D infrastructure and skilled human resources.

In Africa, the mission of STISA-2024 is to "accelerate Africa's transition to an innovation-led, knowledge-based economy". STISA-2024 provides an overall policy direction and priority areas for investment in STI to enable member states to reach Africa's aspirations in the African Union's Agenda 2063, as well as the SDGs. However, evidence suggests that progress in implementing STISA-2024 is very slow: according to data from the UNESCO Institute for Statistics in 2017, sub-Saharan Africa's GERD value as a percentage of GDP was only 0.4 per cent, far from the target of 1 per cent.[126] This is partly due to inadequate budgets for the implementation of STISA-2024, and insufficient monitoring and evaluation, at national, regional and continental levels.[127] Several development actors, including the African Union, AUDA-NEPAD, AfDB and UNECA, have launched initiatives to foster regional STI cooperation. For example, the AfDB initiated the Africa Forum on Science, Technology and Innovation to facilitate the sharing of experiences and analysis of best practices in strengthening STI ecosystems.

The national and regional STI policy frameworks in least developed countries recognize that to achieve national development goals and the global SDGs they must strengthen their STI capacity. The Asia-Pacific region is home to both some of the most technologically advanced, as well as the most deprived, countries in the world. However, despite the existence of several regional and subregional initiatives such as the South Asian Association for Regional Cooperation and ASEAN, they remain disparate and unconnected, and thus do not fully harness the region's vast knowledge and potential. ASEAN has established a Plan of Action on Science, Technology and Innovation for the period 2016–2025. One of its main objectives is to strengthen strategic collaboration between academia, research institutions, networks of centres of excellence and the private sector, to create an effective ecosystem for capability development, technology transfer and commercialization.[128]

As the African academies play an important role in supporting the SDGs and STISA-2024, the Technology Bank is partnering with the Network of African Science Academies to support the establishment and capacity-building of Academies of Science in the least developed countries. These academies can advise Governments on STI policy development. Support from this partnership helped establish the Academy of Sciences in Malawi, an independent organization intended to promote science and engineering and increase their influence in Malawi. This national science academy will help implement Malawi's strategic and national development goals, under the theme "Science Driving Malawi Towards 2063 Agenda" and the Malawi Vision 2063 of "An inclusively wealthy and self-reliant nation". These are national initiatives led by the National Planning Commission and supported by the Malawi Ministry of Education's Directorate of Science, Technology and Innovation (DSTI), and the National Commission for Science and Technology. The Academy of Sciences is a knowledge partner that develops the national science capacities that contribute towards addressing national and regional socioeconomic challenges. In Angola, the Academy of Science was launched in 2020, followed by academies in Lesotho and the Democratic Republic of the Congo in 2021. There are plans to launch academies in Cambodia, the Central African Republic, Chad, Liberia, Niger, Sierra Leone, and the Solomon Islands during 2021.[129]

4.6 From grants to innovative financing

In terms of means and funding mechanisms, grants finance the majority of science and innovation. As reported in the *STI for SDGs Roadmap*, more than 90 per cent of the global total official development finance

125 UNCTAD, *Technology and Innovation Report 2021: Catching Technological Waves* (New York, United Nations publication, 2021), p. 22.
126 See https://au.int/sites/default/files/newsevents/workingdocuments/37841-wd-stisa-2024_report_en.pdf.
127 African Union, *Science, Technology and Innovation Strategy for Africa 2024* (2014), p. 11.
128 UNESCAP, Science, Technology and Innovation for Sustainable Development in Asia and the Pacific: Policy Approaches for Least Developed Countries (Bangkok, United Nations publication, 2016).
129 United Nations, "UN Technology Bank and The Network of African Science Academies support the launch of the Academy of Sciences in Malawi", n.d. Available at https://www.un.org/technologybank/news/un-technology-bank-and-network-african-science-academies-support-launch-academy-sciences-malawi (accessed on 16 December 2021).

(ODF) towards STI is financed by grants.[130] United Nations organizations and bilateral agencies provide most grants, although private philanthropic funders are increasingly important. However, support from private philanthropy still represents only a minor share of support for technology-oriented development finance.[131] Several initiatives can be highlighted, such as the Organization for Women in Science for the Developing World (OWSD), a programme unit of UNESCO. OWSD is the first international forum to unite eminent women scientists from developing and developed countries with the objective of strengthening their role and promoting their representation in scientific and technological leadership. OWSD provides grants to women scientists from the least developed countries to undertake research in engineering and information technology sciences.

Through the Fund for Innovation in Development, AFD offers flexible financing via structured grants to various actors (private, researchers, NGOs) to promote innovation in developing countries.

Furthermore, Google also provided over US$25 million in grant funding to 20 organizations to foster the use of artificial intelligence to help address global challenges.[132] Only United Nations organizations have programmes dedicated to least developed countries. The Technology Bank has a mandate to focus exclusively on these countries (and graduated countries for up to five years after graduation). The initiatives using grants mainly have a global scope (focusing on either developing countries or African countries). Very limited information was identified on grant initiatives targeting least developed countries in the Asia-Pacific region.

Contributions of United Nations organizations and multilateral development banks can be split between grants and loans. This is the case for instance of the Inclusive Digital Economy programmes as well as the LDC Investment Platform, both financed by the United Nations Capital Development Fund. These initiatives provide flexible grants and loan instruments to least developed countries to finance a wide range of products and services in various sectors ranging from finance to agriculture, education, health and transportation. There is also an increase in STI initiatives financed in the field of entrepreneurship in developing countries (with a focus on Africa) that use alternative financing models, such as impact investment, venture capital, and innovation and technology funds. Indeed, according to the *2021 Technology and Innovation Report*, annual equity funding for tech start-ups in Africa doubled to more than US$1 billion in 2018.[133]

These flexible alternative financing models are aimed at generating social and environmental value, as well as financial return. Donors have experimented with different models to manage the inherent risk of innovation and deliver the more cost-effective and high-impact aid. Several key initiatives were identified, mainly financed by multilateral development banks and bilateral organizations, with a focus on sub-Saharan Africa. For instance, Boost Africa is a joint initiative of the AfDB and the European Investment Bank (EIB). Its goal is to enable African companies to become globally competitive by boosting innovation and addressing financing gaps at the earliest and riskiest stages of business creation. The AfDB's Innovation and Entrepreneurship Lab, part of Boost Africa's technical assistance support, has identified and delivered support to 1,080 business organizations and trained 3,267 business owners from 32 African countries.[134] Very limited information was identified on grant initiatives targeting least developed countries in the Asia-Pacific region.

Overall, regardless of the means and financial instruments employed by the main actors to use STI to tackle global challenges in the least developed countries, there is a trend towards multilateral collaboration, whereby multiple actors work in complementarity and try to rely on innovative financing instruments. While many initiatives financed through grant funding and loans have a global scope that targets developing countries, most of the innovative financing instruments target the African continent. The only actor identified to be providing loans and grants targeting countries in the Asia-Pacific

130 OECD, *Connecting ODA and STI for Inclusive Development: Measurement Challenges from a DAC Perspective*, No. DCD/DAC (2019)38 (2019). Available at https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DCD/DAC(2019)38&docLanguage=En.

131 Ibid.

132 Official website of the Google AI Impact Challenge, 2018: https://impactchallenge.withgoogle.com/ai2018 (accessed on 14 July 2021).

133 UNCTAD, *Technology and Innovation Report 2021: Catching Technological Waves – Innovation with equity* (New York, United Nations publication, 2021).

134 European Investment Bank, "EUR 1 billion Boost Africa initiatives scales up support for thousands of young African entrepreneurs" (20 April 2021). Available at https://www.eib.org/en/press/all/2021-130-eur-1-billion-boost-africa-initiative-scales-up-support-for-thousands-of-young-african-entrepreneurs (accessed on 2 September 2021).

region (including least developed countries) is the Asian Development Bank. A clear discrepancy therefore exists in terms of access to innovative financing mechanisms between the least developed countries located in Africa and in the Asia-Pacific region. The Asia-Pacific region is home to some of the most technologically advanced economies in the world, as well as to some of the most technologically deprived. Regional platforms for cooperation such as ASEAN can play an important role in strengthening collaboration within the entire Asia-Pacific region to promote inclusive and sustainable innovation and to advocate for more flexible and innovative financing instruments.[135]

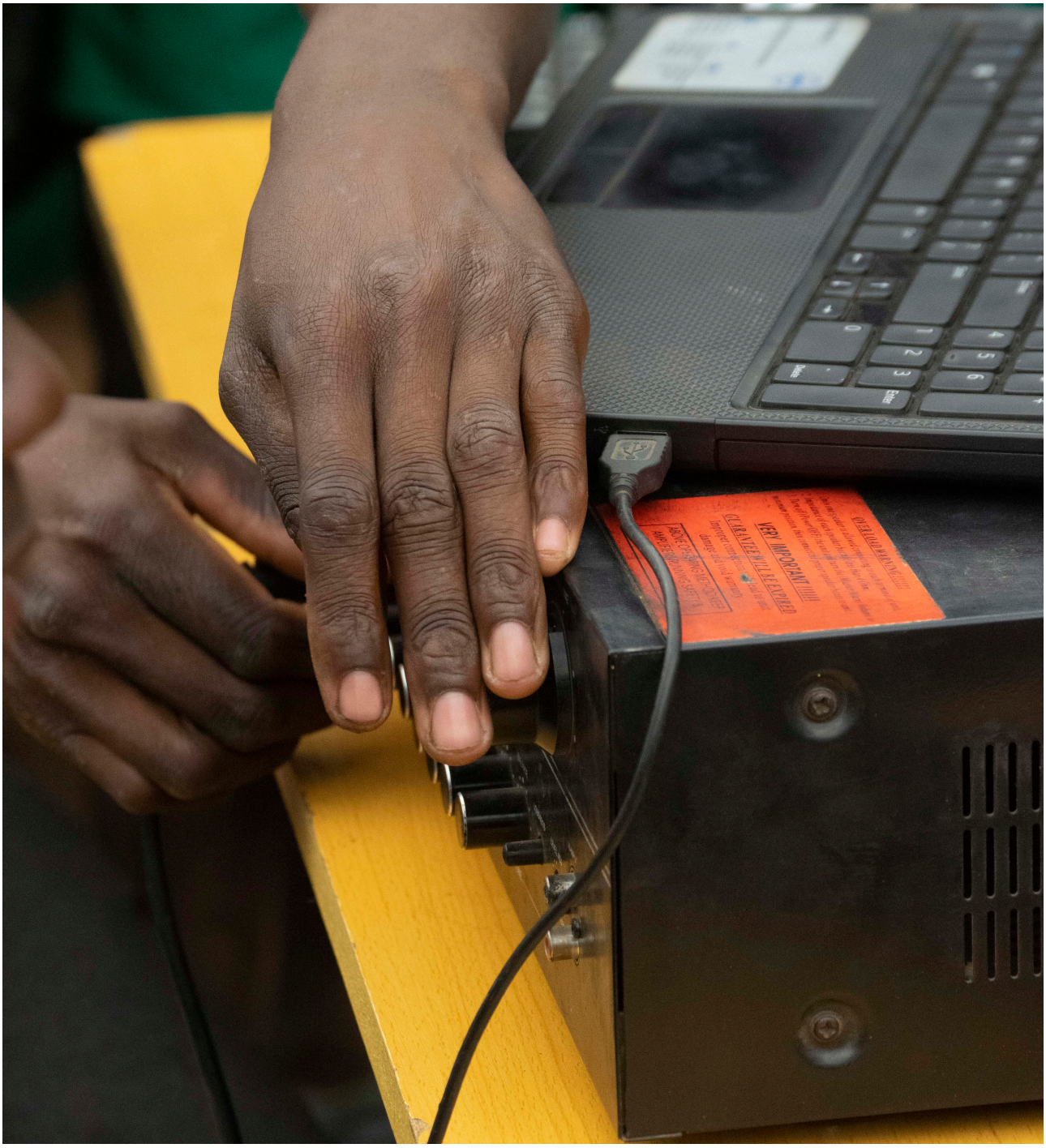


Photo credit: Strategic Agenda

135 UNESCAP, *Science, Technology and Innovation for Sustainable Development in Asia and the Pacific: Policy Approaches for Least Developed Countries* (Bangkok, United Nations publication, 2016). Available at https://www.unescap.org/sites/default/d8files/knowledge-products/STI-LDCs%20book.pdf.

5. Best practices across the least developed countries

Several least developed countries have harnessed the potential of STI in the last 10 years. Even though there is no single recipe for building STI systems and unlocking the promises held by STI development, some least developed countries display unique features that may inspire others.

This section includes examples from some least developed countries that confirm the importance of strong governance of STI systems (with strong leadership and clearly established institutions to steer STI policies) and well-designed policymaking (strategic planning). It also showcases the e-government initiatives and cybersecurity regulations found in some least developed countries and the effectiveness of STI policy instruments such as collaborative research and incubators for start-ups.

5.1 Leadership and institutions: the case of Cambodia

A key element of Cambodia's progress on STI is the reform of its governance system and the Government's involvement in developing STI. In March 2020, the Ministry of Industry and Handicraft was replaced by the Ministry of Industry, Science, Technology and Innovation (MISTI), stating a renewed priority around STI in Government and signalling an effort to encourage scientists and experts on technologies to take part in economic development. As part of this renewed STI governance, the Cambodian Government created two new units within the ministry: the General Department of Science, Technology and Innovation, and the National Institute of Science, Technology and Innovation. Their goal is to meet the practical needs of relevant institutions and to advance the Fourth Industrial Revolution.

This governance choice is the result of a progressive inclusion of STI priorities within the Government of Cambodia. Indeed, the interministerial National Science and Technology Council was established in 2014 under the Ministry of Planning. Renamed the National Council of Science, Technology and Innovation and put under MISTI, it comprises all ministers involved in economic development in Cambodia: the Prime Minister, the Minister for Industry, Science, Technology and Innovation, the Minister for Planning, the Minister for Mining and Energy, the Minister for Agriculture, Forestry and Fisheries, the Minister for Education, Youth and Sports, the Minister for Post and Telecommunications as well as secretaries of state from other ministries.

Furthermore, Cambodia participates in the ASEAN Committee on Science, Technology, and Innovation, which supports ASEAN cooperation on STI and promotes the implementation of programmes and activities in the areas defined in the ASEAN Plan of Action on Science, Technology, and Innovation 2016–2025. In Cambodia, this committee is under the supervision of MISTI.

This governance strategy illustrates two best practices: firstly, the importance of clearly establishing institutions, at the government level, charged with developing STI (for example, MISTI and the National Institute of STI); secondly, the need to involve all ministries in the governance of STI, to make it a shared priority among the administration.

This recognition of STI as a shared national priority is also illustrated by the Government of Cambodia's strategic efforts to establish STI policies and roadmaps and economic development plans. In 2015, the Government of Cambodia adopted the Industrial Development Policy (2015–2025) with some 100 detailed measures for addressing a range of priorities, from skills and technologies to financing and facilitating trade and investment. Then in March 2019, the Prime Minister of Cambodia presented a package of 17 reform measures aimed at improving competitiveness, promoting MSMEs, and attracting FDI at the Government–Private Sector Forum. The measures ranged from reducing logistics costs to lowering electricity tariffs, improving labour law, increasing the ability of MSMEs to access finance, and finalizing the amendment of the Law on Investment and the Law on Special Economic Zones. The aim is to enable the development of industrial clusters and, in turn, new and better-quality employment opportunities for local populations. In early 2020, MISTI promulgated the Five-Year SME Development Plan to create synergies with the current work attached to the Industrial Development Policy and the ASEAN Strategic Action Plan on SME Development 2016–2025 which promotes MSMEs in the region individually and collectively.

On the digital front, under the supervision of the Ministry of Post and Telecommunications (MPTC), the Government of Cambodia has adopted the Law on Telecommunications, the Telecommunications/ICT Development Policy 2020, and the ICT Master Plan 2020. The Law on Telecommunications aims to ensure efficient

use of infrastructure and networks and the provision of effective, safe, high-quality, reliable and affordable telecommunications services. It encourages private sector participation in the development of this sector, ensures fair competition and protects consumers. The Telecommunications/ICT Development Policy 2020 sets certain measures and interventions to develop infrastructure, human capacity, cybersecurity, e-services, and the ICT industry.

Furthermore, Cambodia officially recognized STI as a driver towards achieving the SDGs, its Rectangular Strategy-IV and its Vision 2050. Vision 2050 will be supported by the implementation of the National STI Policy 2020–2030, which was approved in 2019. These major long-term guiding policy documents illustrate the adoption of a resolute reform agenda around STI in Cambodia. They are fundamental tools to direct socioeconomic development towards a new sustainable phase, achieve the national development agenda and develop a vibrant private sector.

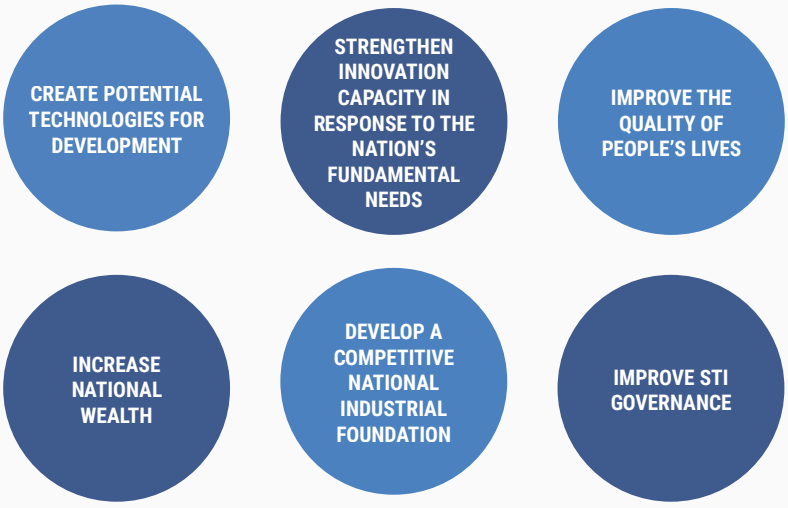
5.2 STI policy and strategic planning: the case of Bangladesh

A distinctive feature of Bangladesh is its strong policy and strategic planning for STI, notably towards digitization. Its first National Science and Technology Policy was formally approved by the Government in 1986, and the revised National Science and Technology Policy 2011 continues to frame science and technology in Bangladesh. The policy foresaw the establishment of an Engineering Research Council, which was created in September 2020.

More specifically, achieving a "Digital Bangladesh" was one of the ambitions of Vision 2021. The National ICT Policy 2015 and 2018 as well as the e-Government Master Plan for Digital Bangladesh (2018) and the Digital Security Act (2018), which led to the establishment of the Digital Security Agency (DSA), have all worked towards this goal. In particular, the Ministry of Education plays a significant role in building a Digital Bangladesh by 2021. It formulated the Master Plan for ICT in Education in Bangladesh 2012–2021, with the aim of reducing the digital divide between urban and rural areas in the education sector and leveraging ICT as a cost-effective tool to enhance the quality of education. The 2019 *Progress Review Report* of this master plan showed that real progress had been achieved, but notably recommended extending the Master Plan for ICT in Education to 2030.

Additionally, the Government of Bangladesh prepared a 20-year Strategic Plan for Higher Education (2006–2026)[136] to improve the quality and relevance of the

The adoption of an STI policy is also a best practice that strengthens the STI foundation and builds national STI capability to do the following:



136 Titled Higher Education Quality Enhancement Project (HEQEP).

teaching and research environment in higher education institutions by encouraging innovation and accountability within universities and by enhancing the technical and institutional capacity of the higher education sector. The targets to be achieved are aligned with the SDGs, the National Education Policy 2010 and the Government's vision of establishing a Digital Bangladesh by 2021.[137]

Very recently, Bangladesh has developed a National Strategy for Artificial Intelligence 2019–2024,[138] which aims to overcome data and talent shortages in the artificial intelligence sector. This strategy identifies seven national priority areas for artificial intelligence: public service delivery; manufacturing; agriculture; smart mobility and transportation; skills and education; finance and trade; and health. The strategy notably plans to fund 1,000 start-ups in artificial-intelligence-related areas during the 2019–2024 period.

The Government is also very active in promoting the development of ICT solutions in the health sector. Furthermore, it approved the National Social Security Strategy in 2015 and its accompanying Action Plan in 2018, with a view to addressing poverty, inequality, risk and vulnerability in the country.

5.3 ICT innovation, e-government and cybersecurity regulation: the case of Rwanda

The dissociation of service execution by state or parastatal entities from payments generated by these services is an important avenue towards modernizing Governments. It presents multiple benefits, including improved service delivery to citizens, transparency, traceability, accountability, cost effectiveness, and reduced corruption. In addition, being able to develop such a service with a sound supporting business model is of paramount importance for sustainability. The Rwandan e-government portal is a best practice, which brings a number of transferable and key learnings for the continent.

The Irembo e-service portal was created in 2014 by the Government of Rwanda in partnership with a Rwandan technology solutions provider that runs e-government programmes. The objective was to create efficient and transparent procedures to effectively improve service delivery by using a profound understanding of local needs and enabling the community to apply for government services (such as a passport, car inspection, or electronic criminal clearance certificate) and pay for these services upfront, without the entities in charge of these services being involved in the payment process. Payments and service execution are therefore dissociated. E-services offered have increased from only five in 2015 to some 89 in 2018 and today, more than 96 services are just a click away for more than 9 million subscribers and thousands of others who are supported by Irembo agents across the country to access online services through the portal.

Several back-end systems are improving the delivery of key government functions in areas such as financial management, public procurement, education, and health. For instance, Irembo is a key component of the Government's response to the COVID-19 pandemic. It has enabled the centralization of reservations for COVID-19 tests, the collection of associated payments and the subsequent dispatching of customers across testing facilities. The immediate consequences are improved financial management and enhanced efficiency at testing sites.

To enable its e-service offering to be scaled up, Rwanda has put in place key building blocks to support government digitization. These include the digitization of public records, the expanded use of management information systems, the roll-out of shared cloud-based infrastructure, the enabling of data exchange between various government entities, and the introduction of a foundational legal and institutional framework related to cybersecurity along with a framework for data protection. The development of the national e-government ecosystem has benefited from strong leadership support along with a robust and centralized institutional framework, and the development of critical enabling platforms such as digital identification, which provides near-universal (98 per cent) identification coverage. It is also benefiting from African talents joining the Irembo team to complement and close the local talent and skills gaps.

137 Bangladesh, Ministry of Planning, *Bangladesh Voluntary National Reviews (VNR) 2020* (Dhaka, General Economics Division, Bangladesh Planning Commission, 2020).
138 Susan Schneegans, Jake Lewis, and Tiffany Straza, eds. *UNESCO Science Report 2021: The Race Against Time for Smarter Development* (Paris, United Nations Educational, Scientific and Cultural Organization, 2021).

5.4 STI policy instruments – research collaboration programmes: the case of the Pacific Islands

Established in 2012, the Pacific Islands Universities Research Network (PIURN) is a consortium of 14 universities in the Pacific Island countries and territories to enable closer and meaningful collaboration among researchers in the consortium. It seeks to identify and address – via research, development and innovation – the social priorities, economic growth, and environmental challenges in the Pacific Island countries and territories.

The University of the South Pacific (USP) based in Fiji functions as a regional university in the area, with branches/campuses located elsewhere. The USP has recently appeared in the 2022 Times Higher Education (THE) World University Rankings[139] (putting it in the top 10 per cent of universities in the world), which has ranked USP in the top 400 universities for "international outlook" and in the top 500 universities for "industry outcome". PIURN allows members to exchange ideas and practices with one another and to pool resources in response to common territorial issues.

The PIURN has identified four main strategic research themes that are in line with the United Nations' SDGs (2015–2030): i) Food Security and Nutrition, and Health and Non-Communicable Diseases; ii) Climate Change and Biodiversity, including Land Degradation; iii) Capacity-Building, and Data and Statistics; and iv) Social Development, Gender Equality and Education. Around this rather recent strategy, the PIURN has succeeded in:

- Structuring a directory of researchers from partner universities.
- Enabling the exchange and hosting of researchers in residence.
- Creating a regional master's degree in Sustainability Science – Climate Change and Environmental Sustainability in the South Pacific. This new programme has been offered since August 2021 through a combination of face-to-face and distance learning from Noumea and Suva (Fiji), and gives priority to students from the region. The programme is internationally oriented, with a mandatory semester of mobility and a professional or research internship. It fully targets the issues and specificities of the South Pacific in terms of climate change, environment and sustainable development.
- Organizing a conference every two years to allow researchers, teachers, third parties and students to exchange on themes common to the different universities. At the third conference of the network held in October 2018, nearly 80 scientific papers from 12 territories and 19 universities in the Pacific region were presented. It aimed to strengthen cooperation and discussions among PIURN members and third parties to design new collaborative projects around a general theme: traditional knowledge, academic knowledge, and current research dynamics of universities in the Pacific region. The fourth conference was held in October 2021.
- Organizing a call for projects once a year to initiate inter-university research collaborations. To this end, the University of New Caledonia (UNC) and the University of the South Pacific (USP) devote a portion of their funds to organizing this initiative.

Research projects that have been carried out directly respond to the fragilities in the Pacific least developed countries:

- Evaluating the Effectiveness of National Adaptation Programme of Action on Climate Change in five Pacific Least Development Countries (LDCs) – The Case of Solomon Islands: This research study focuses on assessing the effectiveness of adaptation strategies used to mitigate the impact of climate change in the Atoll Islands and other selected communities in Solomon Islands, in line with the priorities identified in the 2008 Solomon Islands National Adaptation Programme of Action (NAPA), and will align with lessons learned from NAPAs in the other four Pacific least developed countries.
- Addressing Threats to Traditional Food Security and Diet Quality in the Rural Pacific: This project is concerned with the interactions and mutual influences of food production from traditional Melanesian and Polynesian home gardens and quality diets, and thus community health in Pacific societies. This food production, and ultimately food security, is very closely linked to village lifestyles and the traditional cultures and knowledge systems of rural people. It is threatened by a variety of factors

139 University of the South Pacific, "USP ranked amongst the top 1% of universities in the world", 10 September 2021. Available at https://www.usp.ac.fj/news/usp-ranked-amongst-the-top-10-percent-of-universities-in-the-world/ (accessed on 16 December 2021).

such as population growth, urbanization, and alienation of land for other purposes.

- Creation of a Pacific Academic Network on Migrations and Climate Change: Creation of a visible bilingual academic network to share ongoing research, and creation of useful educational materials to disseminate research results to students, academics, professionals and the public.

- Pacific Islands Neighbor Network for the Access to Local E-databases: Creation of a platform for access to a database on individuals for and by the Pacific in order to promote access to data, organize their use and share the results with the scientific community. The project's first objective is to collaborate with the Pacific Community (SPC) to build a digital portal allowing access to data on the Pacific Islands region. The second objective is to organize the community of researchers in order to promote their use and to add value to studies using these local data.

5.5 STI policy instruments – incubators: the case of Mauritania

Mauritania has recently seen the set-up and launch of several incubators, most notably the Kosmos Innovation Center (KIC) and the Hadina RIMTIC.

The KIC is an incubator that invests in young entrepreneurs and leaders of small businesses who have ideas that could help their country develop. It aims to strengthen entrepreneurship and innovation capacities in sectors other than gas and oil, in order to help create a healthier and more diverse economy. In 2018/2019, it selected over 30 young entrepreneurs to participate in the first Mauritania Innovation Challenge. Aimed at young entrepreneurs and leaders of small businesses, the challenge offers participants a solid capacity-strengthening programme organized as an eight-step journey to develop a market-ready product or service, with a final seed-funding competition at the end. The four-month training path includes a Business Plan Development Programme that provides young start-ups with the opportunity to gain confidence and skills. Throughout the programmes, participants take part in a series of presentations ("pitches") at key stages of their project. They benefit from structured, one-on-one mentoring from an assigned coach, who tests their knowledge after the training courses and provides personalized advice. Participants are guided through the early and fragile stages of growing a business, and learn all about defining a business problem, creating a value proposition, and how to understand and identify a target audience. The programme has a strong leverage effect, as several of the 2018/2019 awardees were able to secure further funds from external funders, in addition to the funds granted by Kosmos Energy.

Another interesting incubator is Hadina RIMTIC. Created in 2014 with the support of co-funding from the French Embassy in Nouakchott, Hadina RIMTIC offers a solid incubation over a period of six months with a training programme covering marketing and communication, legal support, financial management and partnerships. The incubator also organizes an annual innovation competition called the MauriApp Challenge. Many of the applicants showed a real concern to respond to concrete everyday problems through new technologies, for instance applications on diabetes, on safety in taxis, or to denounce corruption. Among awarded projects are: i) an online school management platform connecting schools, parents and students and sharing information on the curriculum, pedagogical tools and student performance monitoring; ii) a crowdfunding platform via SMS, developed by three young Mauritanians in collaboration with the national telecoms operator.

5.6 R&D and crop innovations: the case of Mozambique and Burkina Faso

In many least developed countries, crops innovations hold potential for national food security and economic growth.

Feed the Future Agricultural Innovations (FTF Inova) in Mozambique is a programme aimed at improving the underprivileged conditions of agriculture in Mozambique, in order to increase food availability. The partnership between multiple stakeholders (the Government of Mozambique, the U.S. Agency for International Development (USAID), private sector companies and civil society organizations) will contribute approximately US$21 million between 2017 and 2022. FTF Inova's core goal is to increase investments and incomes in the agriculture sector, in line with Mozambique's agenda to generate better conditions in this sector. To reach this goal, it works on increasing the competitiveness of given value chains, expanding the number of competitive enterprises, upgrading their services and products, and fostering the growth of stakeholder relations within the ecosystem. Moreover, the programme's monitoring activities, as well as flexible financial tools for adapting to market changes, are expected to have a positive impact

in the sector, with new tendencies being replicated in a spillover effect. Importantly, the programme seeks to strengthen public–partner relations in agriculture by supporting the involvement of private investments in the main sectors, including groundnut, cashew, soybean, banana and sesame.

Practically, the programme has conducted research analyses of key crops (e.g. soybeans or sesame), to further understanding and to address root causes of inefficiencies and/or underperformances. Furthermore, it has introduced improved seed varieties to the market, promoted agricultural extension trainings and run informational campaigns that have used radio/SMS, on account of the low levels of Internet access in rural regions. Finally, by building collaborations with financial institutions and loan associations, it has enabled small farmers to access credit lines. It had already generated positive results in 2019, with around US$29 million in sales. Furthermore, to date it has enabled at least 28 new private relationships, not only in the agriculture sector (e.g. through fostering new contacts for radio commercials). Over 16,000 hectares of land have been introduced to new technologies or management practices. As a result, FTF Inova has benefited over 13,000 people (37 per cent women), bringing changes to their farming approaches.

On a similar note, a Burkinabé private company provides improved maize, rice and cowpea seeds to small-scale farmers at affordable prices. While most of the West African market is dominated by traditional seeds, this company focuses on the production and commercialization of improved seeds that can increase yield by 40 per cent. The company exports to Côte d'Ivoire, Guinea, Mali, Senegal and Sierra Leone and has an annual turnover of US$5,371,530. The improved seeds are adapted to the agroecological conditions of local farmers, whom the company trains on production strategy, and are a result of the research produced by the public National Centre of Scientific Research and Technology (CNRST by its French acronym), and notably its Institute of Environment and Agricultural Research. The private company and the institute have developed strong links through a collaboration agreement which secures the production in sufficient quantity of improved seeds and their later private commercialization.

6. Technology Bank's role in the STI landscape

The least developed countries regard digital transformation as the most important STI development trend that can boost productivity, offer better-quality jobs, and even enhance their responses to their social and environmental development challenges. Digitization has already allowed many least developed countries to leapfrog inadequate landline connections to arrive at mobile telephony. To support the creation of a workforce that is able to sustain the digitization trend, the least developed countries must invest in Science, Technology, Engineering and Mathematics (STEM) education. They must also address inequities in access to STEM education and access to digital services when bridging the existing divides (gender, rural/urban, poor).

The least developed countries plan to become more competitive by acting upon their STI governance, from their institutional framework to their policies and instruments. There is no one-size-fits-all solution. Hence, least developed countries make decisions according to their STI development status, their perception of the importance of STI for their development, and their current strengths and weaknesses.

They also plan to strengthen their frugal science systems by strengthening their investments in priority areas such as health, agriculture, natural mineral resources, environment, fight against climate change, and energy. These investments concern researchers, research infrastructures, and research programmes, with some academic–industry linkages (e.g. Bangladesh, Democratic Republic of the Congo, Kiribati, Nepal, Togo) and also sectoral centres of excellence for the advancement of STI (e.g. the United Republic of Tanzania). Fostering research collaboration between national and foreign researchers is also an avenue to advance rapidly, alongside developing and tapping into open science (e.g. Nepal). As funding remains a key challenge, some least developed countries plan to focus primarily on funding applied research (e.g. this was seen as important by Angola, Nepal, Rwanda and Togo). Rwanda viewed its development of a National Research and Innovation Fund as a best practice, while the United Republic of Tanzania saw its establishment of sectoral centres of excellence for advancement of STI in the same light. In terms of gaps, the need for open science was stressed by Nepal, while the need to incentivize and support entrepreneurship development was suggested by Nepal and Bangladesh. Bangladesh also highlighted the need to foster technology transfer for capacity development.

Strengthening their weak technology base is a must for most least developed countries. Some of them plan to foster technology transfer for capacity development (e.g. Bangladesh), or to prepare the human power and pool of professionals working in STI to engage in digitization and the Fourth Industrial Revolution (e.g. Bangladesh, Haiti, Rwanda).

Acting on the business system is also an important avenue. Overall, some least developed countries plan to incentivize and support entrepreneurship development (e.g. Bangladesh, Nepal) or facilitate capital resources (e.g. Rwanda). Some least developed countries also plan to invest in specific value chains such as organic food production or nuclear technology applications in agriculture to improve animal production and reduce animal losses (e.g. Lesotho), precision machinery of spare parts such as wires, magnets, electric motors or generators and quality assembly (e.g. Malawi), or more generally in engaging in the Fourth Industrial Revolution (e.g. Bangladesh).

To ensure that all of the above is happening, well-designed and targeted support from the public sector is key. The least developed countries plan to engage in strengthening their governance by renovating the institutional STI framework (e.g. Bangladesh, the Democratic Republic of the Congo, Kiribati, Togo); designing scientific policy, innovation policy or strategy, or producing STI indicators thanks to R&D and innovation surveys (e.g. Bangladesh, Democratic Republic of the Congo, Kiribati, Nepal, Togo).

Considering this outlook, there are opportunities for the Technology Bank to strengthen its role and for the broader stakeholder community to renew its support and commitment to working with the Technology Bank on these aspects. The Technology Bank will therefore aim to:

- **Strengthen its role as a platform to facilitate understanding and address complex STI issues in the least developed countries.** In other words, it will aim to be a platform addressing the information needs of policymakers and international organizations. Develop further studies on the correlation between innovation and graduation of least developed countries, to advocate for the

crucial role of STI for these countries. Build on the global SDG effort to gain traction for STI, and work in harmony with the TFM and other United Nations organizations at the central and country levels.

- **Promote a dialogue regarding the nuanced nature of innovation in the least developed countries** among Governments, donors, the business sector and innovators. Include the people that intend to get involved in innovation, and the diaspora, which is a vivid source of innovation within the least developed countries. Both groups may not be formally recognized as innovators. Facilitate in a neutral manner. Involve the Regional Economic Communities in Africa, ASEAN in Asia, and the Pacific Islands Forum to ensure that the regional specificities and the diversity of least developed countries are considered. Include discussions on peace, security and regional stability so that these issues are considered within the Innovation Index. Include a discussion on the impact of STI on development challenges in least developed countries.

- **Support the sharing of good and best practices in terms of STI governance among the least developed countries.** Support their knowledge networks to speed up the spread of innovations developed in some least developed countries to other least developed countries.

- **Take action to facilitate sharing of knowledge and technology solutions.** i) Support the sharing of good and best practices in terms of STI governance among and within Governments in least developed countries. ii) Build capacities at different levels to address the often-poor understanding of certain systemic knowledge around STIs, least developed countries and the graduation status (what innovation is, what graduation is, what it takes to innovate, what the state of innovation is within the country, what the use cases are, the purpose of these, how this can be converted into value). iii) Ensure the inclusion of interest groups such as business associations, entrepreneurial networks, incubators, and other independent networks (including civil society organizations, citizens groups and diaspora communities). These groups are key to knowledge diffusion. Facilitate the adoption of innovations developed in some least developed countries in other least developed countries.

7. Future outlook for STI policymakers

As they are contextually relevant and often less resource-intensive, hence more sustainable than in developed countries, least developed countries' innovation efforts are paying off. These successes can play a role in inspiring not only other least developed countries, but also the rest of the world.

An effective STI system should encourage interaction between groups of actors and contribute to promoting the development of technology to meet the needs of society. Least developed countries that decide to embark on the STI journey have to create an environment that allows the development of essential infrastructure, human capital accumulation, and partnerships, as these galvanize innovation policies so that individuals and communities can work to address challenges.

The institutional specificities of least developed countries – historical contexts, democratic trajectories, informality of the productive sector, importance of non-market coordination (trust, reciprocity, community organizations), functional weaknesses of public institutions, role of NGOs – determine learning modes to be grasped in the formulation of development policies. These must be considered for initiatives aimed at enhancing STI in the least developed countries.

The following recommendations can be made:

For decision makers in donor agencies:

- **Support STI investments in the least developed countries as a way to achieve the SDGs.** Commit to funding STI systems building and STI investments in the least developed countries. Strengthen infrastructure to exploit the opportunities of the digital transformation. Ensure that the least developed countries have access to existing technologies at mutually agreed terms that protect, their interests and privacy rights.

- **Ensure that STI development is sustainable; notably that it considers impact on climate change and biodiversity.** The least developed countries can leapfrog and avoid destructive growth policies. For STI development to be sustainable, interventions need to be grounded in the current reality and consider social, cultural, political and environmental interests and factors. Mainstream STI to raise its profile, in recognition of the broad impacts that arise from STI investment. On the one hand, promote efforts to build capacity in use-oriented applied research, and on the other recognize the diverse forms that innovation takes in new products, processes, entry into value chains, creating new markets, and sustainable exploitation of untapped resources.

- **Cooperate on STI to increase global impact.** Care is needed in identifying where donor assistance is best applied. This calls for careful ex ante assessment of intended and unintended outcomes, and even impacts. In a context of scarce resources for policymaking and development support, cooperation and complementarities from the donor community are even more necessary.

- **Support STI governance building and learning capacities as a first step.** Governance frameworks are essential, especially for project selection, monitoring and termination. Locate agenda setting and prioritization at the highest level of government, so that scarce resources may be well targeted to real problems. If possible, try to avoid "pet" projects. Build Governments' capacities on how to cost policy instruments. Build institutional capacities in the informal sector or even promote interactive learning in traditional communities before investing in more expensive and risky activities. Support skills development to reap the benefits of the Fourth Industrial Revolution.

- **Support the strengthening of local innovation ecosystems.** Help build productive capacities to move to higher-value-added production. Build networks among the national innovation systems' actors nationally, regionally and internationally. Explore support for new, existing and potential entrepreneurs. Identify and reduce obstacles to innovation activities in the informal sector. Support existing innovation hubs and business incubators and make sure they are integrated in regional networks. Foster collaborative research and innovation between academia, research institutes, the private sector, and citizens at the national and international level. Introduce innovative financing, using lessons learned from Senegal or the Asian least developed countries that have introduced successful funding instruments. Adapt the financing of informal activities to the local context.

- **Adapt and enhance the measurement of STI in the least developed countries.** Account for the many grass-roots and frugal innovations in the business sector and even in the service sector. In the health sector, class clinical trials as R&D. Develop capacities within Governments to identify, appreciate and account for these. In addition, develop methods and indicators to capture impacts of STI on development challenges and notably climate.

For decision makers in national Governments:

- **Acknowledge the potential of STI to advance** the national development agendas and growth and to achieve societal development. Build capacity for use-oriented applied research that brings knowledge producers together in problem solving.

- **Enhance STI governance and STI systems.** Set up the appropriate governance of STI. Focus on innovation systems at both the national and sectoral levels. Address STI as a holistic system composed not only of researchers and educators but also entrepreneurs, scientific and technology services, and laboratories. Address disincentives to investing in STI; for example, the sector may be perceived to be less profitable than others. Ensure an open innovation-ecosystem by ensuring mobility of the highly skilled.

- **Focus on the unique features of STI systems in the least developed countries.** Support the enabling environment for emergence of grass-root, indigenous and frugal innovation, not only digital and technology. Support their transfer to other least developed countries or even other developed countries, while protecting the intellectual and knowledge property to ensure benefits for the least developed countries. Provide open-science frameworks. Support maker spaces.

- **Address STI system challenges.** Strengthen ties between education and the private sector. Address firms' existing absorptive capacities. Reinforce public science and technology through FDI, imports of equipment and access to licences. Provide priority support for more advanced services technology to farmers for food security purposes. Disseminate relevant information through networks and databases.

- **Foster widespread connectivity outside the capital city and the main cities to connect people.** While there are positive figures on the use of mobile phones, ICT could have even more impact if connectivity became more widespread.

- **Commit efforts to building, strengthening and maintaining complete STI information systems.** Define adequate STI indicators that reflect the unique nature of STI. This concerns R&D inputs, innovation activities, education statistics, and progress towards the SDGs. Define adequate data collection and data management in line with SDG 17 and related Target 17.17 (data, monitoring and accountability).

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Appendix 2. Interviewees

Calovski, Dimo. Economic Affairs Officer, Division of Technology and Logistics at United Nations Conference on Trade and Development.

González Sanz, Angel. Head of Science, Technology and ICT Branch, Division on Technology and Logistics at United Nations Conference on Trade and Development, and Senior Program Specialist at United Nations Inter-Agency Task Team on Science, Technology and Innovation for the Sustainable Development Goals.

Grazzi, Matteo. Senior Specialist, Competitiveness, Technology and Innovation Division at the Inter-American Development Bank.

Kakule, John F. Expert in Education, Science, Technology, Information Technology, Health and Employment at Organisation of African, Caribbean and Pacific States.

Kumpf, Benjamin. Head of Innovation for Development at Organisation for Economic Co-operation and Development.

Matusiak, Monika. Team Leader on Smart Specialisation – Global Outreach at Joint Research Centre, European Commission.

de Meneval, Philippe. Senior Private Sector Development Specialist in the Middle East & North Africa Region at World Bank.

Murenzi, Romain. Executive Director at the World Academy of Sciences.

Pérez Cusó, Marta. Economic Affairs Officer, Division of Technology and Logistics at United Nations Economic and Social Commission for Asia and the Pacific.

Persic, Ana. Chief of Section, Division of Science Policy and Capacity-Building at United Nations Educational, Scientific and Cultural Organization.

Reddy, Rekha. Senior Financial Sector Specialist, Finance, Competitiveness and Innovation Global Practice at World Bank.

Seke, Lukovi. Programme Officer at African Union Development Agency-New Partnership for Africa's Development.

Van den Bergh, Tim. Specialist in 4IR Technology and Sustainable Development at World Economic Forum.

Waithira Ngure, Josephine. Country Manager at Southern Africa Regional Development and Business Delivery Office, African Development Bank.

Appendix 3. Data on science, technology and innovation in least developed countries

Tables on headline indicators with latest available data for each individual country are provided in Tables 7 to 9. Please note that these are different to the tables used in Chapter 3 of this report, which were based on all data available from 2000–2020. Averages based on latest available data per graduation class for the headline indicators are provided in Figures 18 to 20.

Figure 18. Overview of averages per graduation class on science headline indicators; based on latest available data for each country

	Enrolment in tertiary education per million capita	PhD students per million capita	R&D personnel per million capita	Female R&D personnel (%)	Scientific publications per million capita	Scientific citations per million capita	Government expenditure on R&D [GERD] (%)
Average, all countries	**27,009**	**710**	**3,560**	**37%**	**967**	**1,799**	**0.78%**
LDCs (mean)	**7,890**	**52**	**303**	**26%**	**47**	**36**	**0.25%**
Average, LDCs meeting criteria for first time	8,697	145	497	31.0%	42	37	0.32%
Average, LDCs meeting criteria 2 consecutive times	17,162	9	63	72.0%	26	19	0.03%
Average, LDCs recommended for graduation	-	-	-	-	203	84	-
Average, LDCs scheduled for graduation between 2023 and 2026	12,640	11	813	17.0%	90	66	0.12%
Average, remaining LDCs	6,407	40	231	28.0%	30	27	0.28%

Figure 19. Overview of averages per graduation class on technology headline indicators; based on latest available data for each country

	Proportion of population with access to electricity (%)	Proportion of population covered by at least a 2G network (%)	Fixed Internet broadband subscriptions (%)	Mobile money account (% age 15+)	Gender difference for mobile money account (% age 15+)	Email usage among firms (%)	Website usage among firms (%)	Technicians per million capita	Proportion of medium- and high-tech manufacturing value added (%)	High-tech exports minus reimports (% of manufactured trade)
Average, all countries	**87%**	**95%**	**15.5%**	**23%**	**-1%**	**70%**	**45%**	**634**	**24.3%**	**10.1%**
LDCs (mean)	**56%**	**86%**	**0.6%**	**28%**	**5%**	**52%**	**28%**	**55**	**9.2%**	**5.0%**
Average, LDCs meeting criteria for first time	70.0%	92.0%	1.00%	22.0%	1.8%	63.0%	40.0%	68	**19.1%**	**1.2%**
Average, LDCs meeting criteria 2 consecutive times	84.0%	96.0%	0.10%	69.0%	18.0%	33.0%	14.0%	19	**7.6%**	**2.9%**
Average, LDCs recommended for graduation	98.0%	60.0%	2.00%	-	-	-	-	-	**-**	**7.7%**
Average, LDCs scheduled for graduation between 2023 and 2026	82.0%	82.0%	1.60%	27.0%	8.4%	50.0%	28.0%	231	**6.3%**	**9.5%**
Average, remaining LDCs	44.0%	84.0%	0.30%	28.0%	4.7%	53.0%	27.0%	36	**8.0%**	**4.4%**

Figure 20. Overview of averages per graduation class on innovation headline indicators; based on latest available data for each country

	Firms that spend on R&D (%)	Firms that introduced innovation new to the firm (%)	Growth of innovative companies (scale 1-7 (highest))	Granted patents per million capita	Funded start-ups in crunchbase	Attitude towards entreprenarial risk (scale 1-7 (highest))	Share of firms engaging in R&D-based innovation (%)	Share of firms engaging in non-R&D-based innovation (%)
Average, all countries	**15%**	**36%**	**4.1**	**320.4**	**-**	**4.0**	**12%**	**34%**
LDCs (mean)	**15%**	**39%**	**3.6**	**11.9**	**106**	**3.5**	**11%**	**39%**
Average, LDCs meeting criteria for first time	13.0%	36.0%	4.1	8.1	82	380.0%	9.0%	38.0%
Average, LDCs meeting criteria 2 consecutive times	12.0%	27.0%	-	0.0	104	-	9.0%	35.0%
Average, LDCs recommended for graduation	-	-	-	357	0	-	-	-
Average, LDCs scheduled for graduation between 2023 and 2026	11.0%	38.0%	3.7	3.1	391	3.6	10.0%	51.0%
Average, remaining LDCs	16.0%	40.0%	3.6	2.5	52	3.5	13.0%	38.0%

Table 7. Overview of the state of science in least developed countries. Average values for 2000–2020.

Country	R&D personnel (per million capita)	No. of PhD students (headcount per million capita)	Enrolment in tertiary education (per million capita)	Scientific citations (per million capita)	Scientific publications (per million capita)
Africa					
Angola	87	11.3	4 587	36	2.6
Benin			8 982	596	31.6
Burkina Faso	110	42.8	3 568	384	22.1
Burundi	86	26.5	2 901	65	3.9
Central African Republic			2 178	153	9.0
Chad	195	42.2	1 620	48	2.5
Comoros			5 880	147	11.8
Democratic Republic of Congo	452	20.2	5 763	18	1.1
Djibouti			2 339	166	16.4
Eritrea			5 912	210	14.9
Ethiopia	160	11.6	3 945	214	15.9
The Gambia	282	17.4	2 098	3 112	71.1
Guinea	260		7 514	110	5.3
Guinea-Bissau			2 500	503	21.2
Lesotho	89	18.2	7 164	220	19.4
Liberia			12 519	188	8.4
Madagascar	165	25.0	3 466	180	10.8
Malawi	239	15.6	489	592	27.2
Mali	125	27.4	4 332	260	12.0
Mauritania	642	276.0	4 026	137	10.4
Mozambique	106	5.7	3 713	237	9.0
Niger	58		1 619	117	6.5
Rwanda	75	13.0	4 950	354	18.6
Sao Tome and Principe			2 578	434	24.4
Senegal	926	234.5	8 567	573	40.7
Sierra Leone			1 722	195	9.9
Somalia				14	1.3
South Sudan				7	1.3
Sudan	641	112.0	12 913	187	14.2
Togo	199	74.6	9 620	210	16.6
Uganda	75	15.7	3 459	622	28.3
United Republic of Tanzania	110	11.5	1 916	433	20.7
Zambia	153	15.1	3 947	527	23.2

Country	R&D personnel (per million capita)	No. of PhD students (headcount per million capita)	Enrolment in tertiary education (per million capita)	Scientific citations (per million capita)	Scientific publications (per million capita)
Asia					
Afghanistan			4 444	69	2.9
Bangladesh			11 188	224	20.0
Bhutan			9 507	1 301	84.9
Cambodia	155	8.6	8 590	320	16.1
Lao People's Democratic Republic			13 311	428	24.3
Myanmar	63	5.7	12 916	55	4.3
Nepal	1049		10 830	453	34.2
Timor-Leste			13 139	124	14.0
Yemen			10 795	146	11.1
Oceania					
Kiribati				507	57.8
Solomon Islands				921	46.8
Tuvalu				3969	204.1
North America					
Haiti				124	6.4

Source: Adapted from UNESCO and SCImago (2021).

Table 8. Overview of the state of technology in least developed countries. Average values for 2000–2020.

Country	Email usage among firms (%)	Proportion of medium- and high-tech manufacturing value added (%)	Proportion of population covered by at least a 2G network (%)	Proportion of population with access to electricity (%)	Technicians (headcount per million capita)	Website usage among firms (%)
Africa						
Angola	31%	4%	85%	35%	26	**19%**
Benin	64%		75%	31%		**26%**
Burkina Faso	58%		59%	14%	24	**17%**
Burundi	54%	3%	61%	6%	14	**19%**
Central African Republic	57%	9%	48%	10%		**38%**
Chad	38%		61%	7%	17	**18%**
Comoros			77%	62%		
Democratic Republic of Congo	27%		50%	13%	23	**12%**
Djibouti	72%		78%	57%		**41%**
Eritrea	28%	8%	59%	40%		**6%**
Ethiopia	77%	11%	60%	34%	28	**39%**
The Gambia	43%	20%	83%	44%	91	**18%**
Guinea	39%		84%	27%	48	**14%**

Country	Email usage among firms (%)	Proportion of medium- and high-tech manufacturing value added (%)	Proportion of population covered by at least a 2G network (%)	Proportion of population with access to electricity (%)	Technicians (headcount per million capita)	Website usage among firms (%)
Guinea-Bissau	36%		75%	17%		9%
Lesotho	44%		68%	25%	23	19%
Liberia	39%		60%	19%		9%
Madagascar	69%	3%	47%	18%	18	27%
Malawi	61%	10%	73%	9%	92	28%
Mali	50%		60%	26%	40	30%
Mauritania	61%		73%	33%	4	25%
Mozambique	28%	11%	80%	17%	48	27%
Niger	66%	24%	49%	13%	12	28%
Rwanda	58%	7%	91%	16%	7	32%
Sao Tome and Principe			64%	61%		
Senegal	54%	23%	90%	53%	58	25%
Sierra Leone	22%		82%	17%		8%
Somalia			61%	22%		
South Sudan	51%		38%	4%		26%
Sudan	67%		70%	39%	135	65%
Togo	75%		88%	35%	80	21%
Uganda	35%	11%	78%	18%	20	15%
United Republic of Tanzania	36%	24%	75%	18%	17	19%
Zambia	58%	11%	73%	26%	51	34%
Asia						
Afghanistan	56%	10%	85%	63%		23%
Bangladesh	38%	15%	86%	58%		21%
Bhutan	65%		72%	73%		31%
Cambodia	53%	26%	93%	46%	62	31%
Lao People's Democratic Republic	33%	6%	81%	69%		22%
Myanmar	27%	11%	76%	54%	19	14%
Nepal	47%	9%	67%	63%	344	25%
Timor-Leste	45%		77%	53%		14%
Yemen	19%	10%	77%	60%		17%
Oceania						
Kiribati	-	-	72%	81%		
Solomon Islands	84%	-	82%	33%		25%
Tuvalu	-	-	21%	98%		
North America						
Haiti	-	5%	62%	37%		

Source: Adapted from SE4ALL, ITU UNESCO and WBES (2021).

Table 9. Overview of the state of innovation in least developed countries. Average values for 2000–2020.

Country	Firms that newly introduced innovation (%)	Firms that invest in R&D (%)	Government expenditure on R&D (%)	Granted patents (no. per million capita)	Firms engaging in non-research and development innovation (%)
Africa					
Angola			0.03%	0.01	
Benin	34%	• 14%		2.30	9%
Burkina Faso			0.23%	1.38	
Burundi	45%	31%	0.16%	0.42	30%
Central African Republic	49%	45%		1.20	
Chad	36%	13%	0.30%	0.85	10%
Comoros				0.65	
Democratic Republic of Congo	38%	23%	0.16%	0.00	
Djibouti	33%	18%		0.05	15%
Eritrea				0.19	
Ethiopia	31%	12%	0.29%	0.01	10%
The Gambia	45%	11%	0.04%		10%
Guinea	24%	7%		0.75	5%
Guinea-Bissau					
Lesotho	8%	1%	0.04%	0.29	0%
Liberia	54%	11%		0.11	9%
Madagascar			0.12%	0.20	
Malawi	54%	18%		0.06	17%
Mali	38%	11%	0.35%	1.38	9%
Mauritania	59%	24%	0.01%	1.35	23%
Mozambique	35%	8%	0.33%	0.16	5%
Niger	33%	8%		1.01	6%
Rwanda	37%	19%	0.65%	0.08	15%
Sao Tome and Principe	-			1.45	
Senegal	50%	9%	0.43%	4.96	7%
Sierra Leone	26%	11%		0.08	
Somalia				0.00	
South Sudan	48%	18%		0.00	
Sudan	56%	25%	0.37%	3.83	25%
Togo	38%	18%	0.24%	1.73	12%
Uganda	67%	30%	0.29%	0.01	28%
United Republic of Tanzania	51%	13%	0.41%	0.03	10%
Zambia	42%	19%	0.07%	0.67	13%

Country	Firms that newly introduced innovation (%)	Firms that invest in R&D (%)	Government expenditure on R&D (%)	Granted patents (no. per million capita)	Firms engaging in non-research and development innovation (%)
Asia					
Afghanistan	45%	21%		0.05	17%
Bangladesh	31%	17%		0.12	17%
Bhutan	44%	7%		0.21	7%
Cambodia	32%	42%	0.08%	0.01	31%
Lao People's Democratic Republic	18%	2%	0.04%		
Myanmar	19%	2%	0.09%	0.01	1%
Nepal	51%	7%	0.21%	0.05	7%
Timor-Leste	38%	22%			18%
Yemen	44%	6%		0.17	6%
Oceania					
Kiribati	-			18.29	
Solomon Islands	42%	20%			18%
Tuvalu	-				
North America					
Haiti	-	-	-	1.08	

Source: Adapted from WBES and WIPO (2021).

Appendix 4. Methods of data collection for innovative indicators

To achieve an overview of the level of activity of the least developed countries in the four chosen thematic areas (Agriculture, Health, Climate Change and Energy), three highly innovative software programs were used:

- Scopus, a global database of scientific papers and books
- Meltwater, a firm that gathers social media posts and news articles with a global coverage
- Crunchbase, a firm that collects information about innovative companies worldwide.

The data gathered by these programs have been used to construct innovative indicators on the state of STI in least developed countries, and four thematic areas have been chosen.

Keywords

In order to search in each of these three software programs, sets of keywords needed to be chosen. These are provided in Table 10 and are based on (but differ slightly from) the keyword searches that Scopus uses and recommends for search strings for the SDGs.[140]

Meltwater search

Meltwater collects social media posts and news articles from countries around the globe. Users can search within this software by filtering by both the location where the article is published and keywords in the article's content. As soon as the search is activated, Meltwater starts collecting data. It is important to note that Meltwater cannot search news articles published in the past: only articles published on the day of the search are included in the results. To increase the relevancy of the search results, the initial English search string was translated into 22 languages, although 62 local official languages were not included in the search. These 22 languages were chosen based on the availability of the languages in the Google Translate plugin, and such that for each least developed country, at least one official language was included.

Based on the Meltwater searches, a number of outputs were created:

- For the news articles that were found based on the STI keywords, the relative attention for science, technology and innovation was determined and reported on for each least developed country. The relative attention is expressed as the share of news articles that were found on the individual fields of science, technology and innovation, compared to all STI keywords.
- For the four thematic areas, the relative attention for each area was found in a similar way: it is expressed as the share of news articles that were found on the individual thematic areas, compared to all articles found for all thematic keywords.
- For each least developed country, the keywords for which news articles were found were collected, as well the frequency with which articles were found based on these keywords. Based on these keywords and their frequencies, wordclouds were made

140 Scopus, "Sustainable Development Goals FAQs" (2021). Available at https://service.elsevier.com/app/answers/detail/a_id/31662/supporthub/scopuscontent/ (accessed on 7 December 2021).

for each thematic area and each least developed country.

Scopus search

In Scopus, the database with publications, a search similar to the Meltwater search was conducted. Here, the number of publications per thematic area was collected based on the appearance of keywords in the title and/or abstract, and whether an affiliation of one or more of the authors was based in the least developed country. Based on the number of publications from that country in a thematic area, and the total number of publications in that country, the percentage of publications in that least developed country for a specific thematic area was examined.

Crunchbase search

In crunchbase, the database with innovative companies, a similar search was conducted as for the Scopus search. In this case, the search was based on the keywords for the thematic areas, and whether the headquarter of the company is in a least developed country. Also, the total number of innovative companies was collected per least developed country. Based on the number of companies in a thematic area and the total number of companies, the relative attention for a thematic area among innovative companies was examined.

Table 10. Overview of keywords used for STI and four thematic areas for searches in various software programs

Science, technology and innovation	Health and COVID-19 *Related to SDG 3*	Renewable energy *Related to SDG 7*	Climate adaptation *Related to SDG 1 and 11*	Agriculture *Related to SDG 2*
Science:	Health	energy efficiency	Disaster Risk Reduction	Agriculture
Science, Research	Human AND Disease	energy consumption	DRR	Agricultural
Technology:	Human AND Illness	energy transition	Green Climate Fund	food chain
Technology	Human AND medicine	clean energy	clean development mechanism	food chains
Innovation:	Corona	energy policy	Climate AND	nitrogen cycle
Innovation	Covid	Renewable	adaptive	nitrogen cycles
	sars-cov-2	Renewables	climate adaptation	land tenure rights
	Biontech*	smart grid	Climate AND	smallholder farm
	Pfizer*	smart grids	adapt	Smallholder AND
	Johnson*	electricity consumption	climate resilience	fishery
	Janssen*	clean fuel	Climate AND	Smallholder AND
	Moderna*	clean cooking fuel	resilient	forestry
	AstraZeneca*	Photovoltaic	Innovation	Smallholder AND
	Sputnik*	hydrogen production	climate risk	Food
	Sinovac*	lithium-ion batteries	climate risks	Smallholder AND
	Sinopharm*	lithium-ion battery	Climate AND	pastoral
	cansino biological*	rural electrification	education	food security
	working from home	energy access	climate hazard	food insecurity
		low-carbon	climate hazards	food production
		energy governance	Climate AND	land right
		climate action	island	land rights
		climate equity	Climate AND	land reform
		climate finance	islands	resilient agricultural practices
		climate investment	Climate AND	Agroforestry

Science, technology and innovation	Health and COVID-19 *Related to SDG 3*	Renewable energy *Related to SDG 7*	Climate adaptation *Related to SDG 1 and 11*	Agriculture *Related to SDG 2*
		climate mitigation	small island developing states	agricultural innovation
		climate policy	Climate AND	land use
		climate policies	sea level	land uses
		greenhouse gas	Climate AND	land degradation
		greenhouse gases	sea levels	soil degradation
		UNFCCC		LULUCF
		Climate AND		land conservation
		Emission		sustainable land management
		Climate AND		
		emissions		

Note: Keywords indicated with * were not included in the searches in Crunchbase, since they are companies themselves, and the Crunchbase database collects companies. For searches in Meltwater, the keywords were translated into various languages.

Table 11. Languages spoken in the least developed countries and languages used for Meltwater search

Least developed country	Language(s) spoken	Languages included in Meltwater search	Languages not included in Meltwater search
Afghanistan	Dari / Farsi	Dari / Farsi	
Angola	Portuguese	Portuguese	
Bangladesh	Bengali, English	Bengali, English	
Benin	French	French	
Bhutan	English	English	
Burkina Faso	French	French	
Burundi	Kirundi, French, English, Swahili	French, English, Swahili	Kirundi
Cambodia	Khmer	Khmer	
Central African Republic	French, Sangho	French	Sangho
Chad	French, Arabic	French, Arabic	
The Comoros	Comorian, Arabic, French	Arabic, French	Comorian
Democratic Republic of the Congo	French, Kituba, Swahili, Lingala, Tshiluba	French, Swahili	Kituba, Lingala, Tshiluba
Djibouti	French, Arabic	French, Arabic	
Eritrea	Amharic, Arabic, English, Tigrinya	Amharic, Arabic, English	Tigrinya
Ethiopia	Amharic, Oromo	Amharic	Oromo
The Gambia	English, Mandinka, Wolof	English	Mandinka, Wolof
Guinea	French, Pular, Mandinka, Susu, Kissi, Kpelle, Toma	French	Pular, Mandinka, Susu, Kissi, Kpelle, Toma
Guinea-Bissau	Portuguese, French, Portuguese Creole	Portuguese, French, Portuguese Creole	
Haiti	Haitian Creole, French	French	Haitian Creole
Kiribati	Kiribati (/ Gilbertese / Taetae), English	English	Kiribati (/ Gilbertese / Taetae)

Least developed country	Language(s) spoken	Languages included in Meltwater search	Languages not included in Meltwater search
Lao People's Democratic Republic	Lao	Lao	
Lesotho	Southern Sotho, English	Southern Sotho, English	
Liberia	English, Kpelle, Bassa, Grebo, Dan, Kru, Mano, Loma, Mandingo	English	Kpelle, Bassa, Grebo, Dan, Kru, Mano, Loma, Mandingo
Madagascar	Malagasy, French	Malagasy, French	
Malawi	Chichewa / Nyanja, English	Chichewa / Nyanja, English	
Mali	French, Arabic, English, Fulani, Mandinka	French, Arabic, English	Fulani, Mandinka
Mauritania	Arabic, Fula, Soninke, Wolof	Arabic	Fula, Soninke, Wolof
Mozambique	Portuguese, Swahili, Mwani, Chewa, Tsonga	Portuguese, Swahili	Mwani, Chewa, Tsonga
Myanmar	Burmese	Burmese	
Nepal	Nepali	Nepali	
Niger	French, Arabic, Buduma, Fulfulde, Goumanchéma, Hausa, Kanuri, Zarma, Songhai, Tamasheq, Tassawaq, Tebu	French, Arabic	Buduma, Fulfulde, Goumanchéma, Hausa, Kanuri, Zarma, Songhai, Tamasheq, Tassawaq, Tebu
Rwanda	Kinyarwanda, English, French, Swahili	Kinyarwanda, English, French, Swahili	
Sao Tome and Principe	Portuguese, Portuguese Creole	Portuguese, Portuguese Creole	
Senegal	Arabic, Balanta, Jola-Fonyi, Mandinka, Mandjak, Mankanya, Noon, Pulaar, Serer, Soninke	Arabic	Balanta, Jola-Fonyi, Mandinka, Mandjak, Mankanya, Noon, Pulaar, Serer, Soninke
Sierra Leone	English, Portuguese Creole	English, Portuguese Creole	
Solomon Islands	English	English	
Somalia	Somali, Arabic, English, Italian	Somali, Arabic, English, Italian	
South Sudan	Arabic, English, Nuer, Murle, Luo, Dinka, Ma'di, Otuho, Zande	Arabic, English	Nuer, Murle, Luo, Dinka, Ma'di, Otuho, Zande
Timor-Leste	English, Indonesian, Portuguese, Tetum	English, Indonesian, Portuguese	Tetum
Togo	French, Ewe, Kabiye	French	Ewe, Kabiye
Tuvalu	Tuvaluan, English	English	Tuvaluan
Uganda	English, Swahili	English, Swahili	
United Republic of Tanzania	English, Swahili	English, Swahili	
Yemen	Arabic	Arabic	
Zambia	English, Bemba, Nyanja (/ Chichewa), Tonga	English, Nyanja (/ Chichewa)	Bemba, Tonga
All countries		Dari / Farsi, Portuguese, Bengali, English, French, Arabic, Khmer, Swahili, Amharic, Portuguese Creole, Lao, Southern Sotho, Malagasy, Chichewa / Nyanja, Burmese, Nepali, Kinyarwanda, Somali, Italian, Indonesian	Kirundi, Sangho, Comorian, Kituba, Lingala, Tshiluba, Tigrinya, Oromo, Mandinka, Wolof, Pular, Mandinka, Susu, Kissi, Kpelle, Toma, Haitian Creole, Kiribati (/ Gilbertese / Taetae), Kpelle, Bassa, Grebo, Dan, Kru, Mano, Loma, Mandingo, Fulani, Mwani, Chewa, Tsonga, Buduma, Fulfulde, Goumanchéma, Hausa, Kanuri, Zarma, Songhai, Tamasheq, Tassawaq, Tebu, Balanta, Jola-Fonyi, Mandinka, Mandjak, Mankanya, Noon, Pulaar, Serer, Soninke, Nuer, Murle, Luo, Dinka, Ma'di, Otuho, Zande, Tetum, Ewe, Kabiye, Tuvaluan, Bemba, Tonga

Appendix 5. Survey methodology

The United Nations Technology Bank for Least Developed Countries (Technology Bank) surveyed all 46 least developed countries in the framework of an inaugural high-level publication on the state of science, technology and innovation (STI) in these countries.

The survey was shared by email with key governmental actors representing the main STI institution in their respective countries. Several reminders were sent by email, phone, and text messages (via WhatsApp) to ensure that stakeholders received the survey and had all the information they needed. The Technopolis Group survey team provided additional guidance to respondents when they needed help accessing and filling in the survey.

A total of 25 out of 46 countries completed the survey, giving a response rate of 54 per cent. However, a total of 29 submissions were received: four countries (Bangladesh, Malawi,[141] Rwanda and Niger) submitted two responses; the analysis gives more weight to the response from the main national STI institution. Some responses involved multiple stakeholders.

The table presents the survey respondents.

Survey respondents

Country	Institution	Position
Angola	Angolan Academy of Sciences	Coordinator of the Installing Commission
Bangladesh (respondent n°1)	Information and Communication Technology Division (ICTD)	Joint Secretary
Bangladesh (respondent n°2)	Information and Communication Technology Division	Additional Secretary
Benin	Directorate General for Scientific Research and Innovation (DGRSI)	Director General for Scientific Research and Innovation
Burkina Faso	Ministry of Higher Education, Scientific Research and Innovation (MESRSI)	Director General of Sectoral Studies and Statistics (DGESS)
Burundi	Directorate General for Science, Technology and Research	Director General for Science, Technology and Research
Comoros	Ministry of Posts, Telecommunications, Digital Economy in charge of Information	Consultant to the Ministry
Democratic Republic of the Congo	Ministry of Scientific Research and Technological Innovation	Director of the Valorization of Research Results
Ethiopia	Ministry of Science and Higher Education	Director General for Science and Research Affairs
The Gambia	Ministry of Higher Education, Research, Science and Technology	Director of Science, Technology and Innovation
Haiti	Ministry of National Education and Vocational Training	Director of the Educational Technology Unit

141 Note that Malawi provided a survey form in PDF format (instead of a submission via KoBoToolbox) due to technical issues encountered by the respondent. The data provided were analysed qualitatively but could not be computed quantitatively.

Country	Institution	Position
Kiribati	Ministry of Information, Communication, Transport and Tourism Development	Director of ICT
Lao People's Democratic Republic	Ministry of Technology and Communications	Head of Statistics
Lesotho	Department of Science and Technology	Director
Madagascar	Ministry of Higher Education and Scientific Research	
Malawi (respondent n°1)	Directorate of Science, Technology and Innovation, Ministry of Education, Malawi Government	Director
Malawi (respondent n°2)	National Commission for Science and Technology	Director General
Mozambique	Ministry of Science, Technology and Higher Education	National Director of Science, Technology and Innovation
Nepal	Ministry of Education, Science and Technology	Under-Secretary (Technical)
Niger (respondent n°1)	Ministry of Higher Education and Research	Director of Extension and Technology Transfer at the Directorate General for Research and Innovation
Niger (respondent n°2)	Ministry of Higher Education and Research	Director of Technology and Innovation
Rwanda (respondent n°1)	National Council for Science and Technology (NCST)	Head of Science, Technology Development and Outreach Department
Rwanda (respondent n°2)	Ministry of ICT and Innovation	Director General of Innovation and Emerging Technologies
Senegal	Directorate General for Research and Innovation/ Ministry of Higher Education, Research and Innovation	STI Data Officer
Timor-Leste	National Institute for Science and Technology (INCT)	Executive President
Togo	Scientific and Technical Research Directorate	Research assistant
Uganda	Office of the President, Science, Technology and Innovation	Commissioner for Technology Development
United Republic of Tanzania	Ministry of Education, Science and Technology	Director of Science, Technology and Innovation
Zambia	Ministry of Higher Education	Assistant Director


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