Rapid growth in scientific publishing on cross-cutting strategic technologies in least developed countries over 2011–2019 reflects national policy priorities

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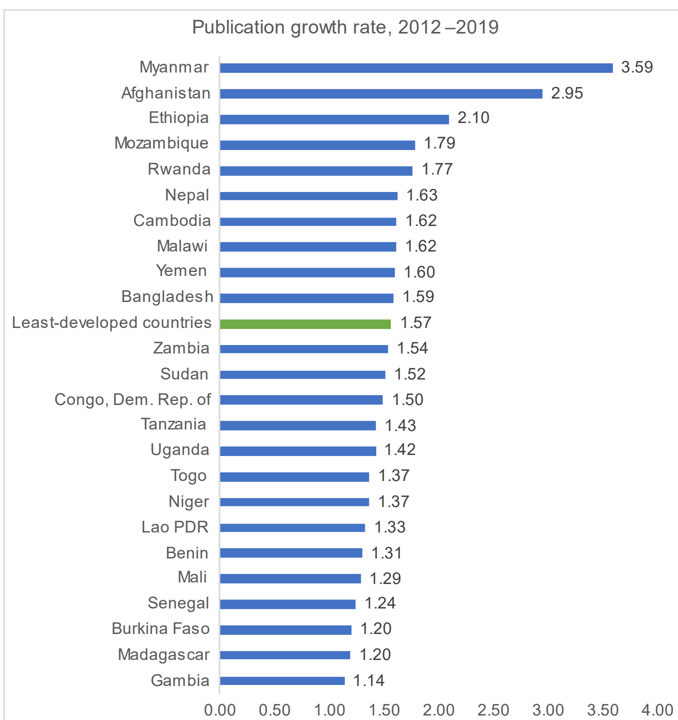
Abstract

Growth in least developed countries in scientific publishing on cross-cutting strategic technologies such as artificial intelligence & robotics, energy, bioinformatics and materials science outpaced that of more developed countries between 2011 and 2019. Drawing upon the UNESCO Science Report (2021), this brief summarizes these publishing trends and discusses policies and strategies adopted by LDCs that underpin these trends. Least developed countries are embarking on the same transition to 'green' and digital societies as more developed countries, in order to achieve their development goals, including poverty reduction and universal access to energy and Internet. This dual transition is a vital element of their industrialization strategies, but LDCs face a major challenge in keeping up with the rapid pace of technological progress. We suggest several avenues for tackling this challenge, including respect for the right to science and scientific freedom, investment in university-based tech incubators to foster technology transfer to the private sector, stronger intellectual property protection and greater international scientific collaboration in cross-cutting strategic technologies.

Introduction

Scientific publishing in least developed countries (LDCs) has outpaced average growth since 2011 and even accelerated since 2015. Between 2015 and 2019, the volume of scientific publications worldwide grew by 20.7% but the rate for LDCs was as high as 70.5%. The number of scientific publications per million inhabitants in LDCs surged from 11 (2011) to 15 (2015) to 23 (2019) [UNESCO, 2021a]. There were impressive gains in scientific output in many countries, in a trend led by Myanmar, Afghanistan and Ethiopia (Figure 1). This trend cannot be explained solely by the growth observed in researcher density in LDCs, which progressed by 26% between 2015 and 2019.

Figure 1. Scientific publications from least developed countries by growth rate, 2012–2019 (%)

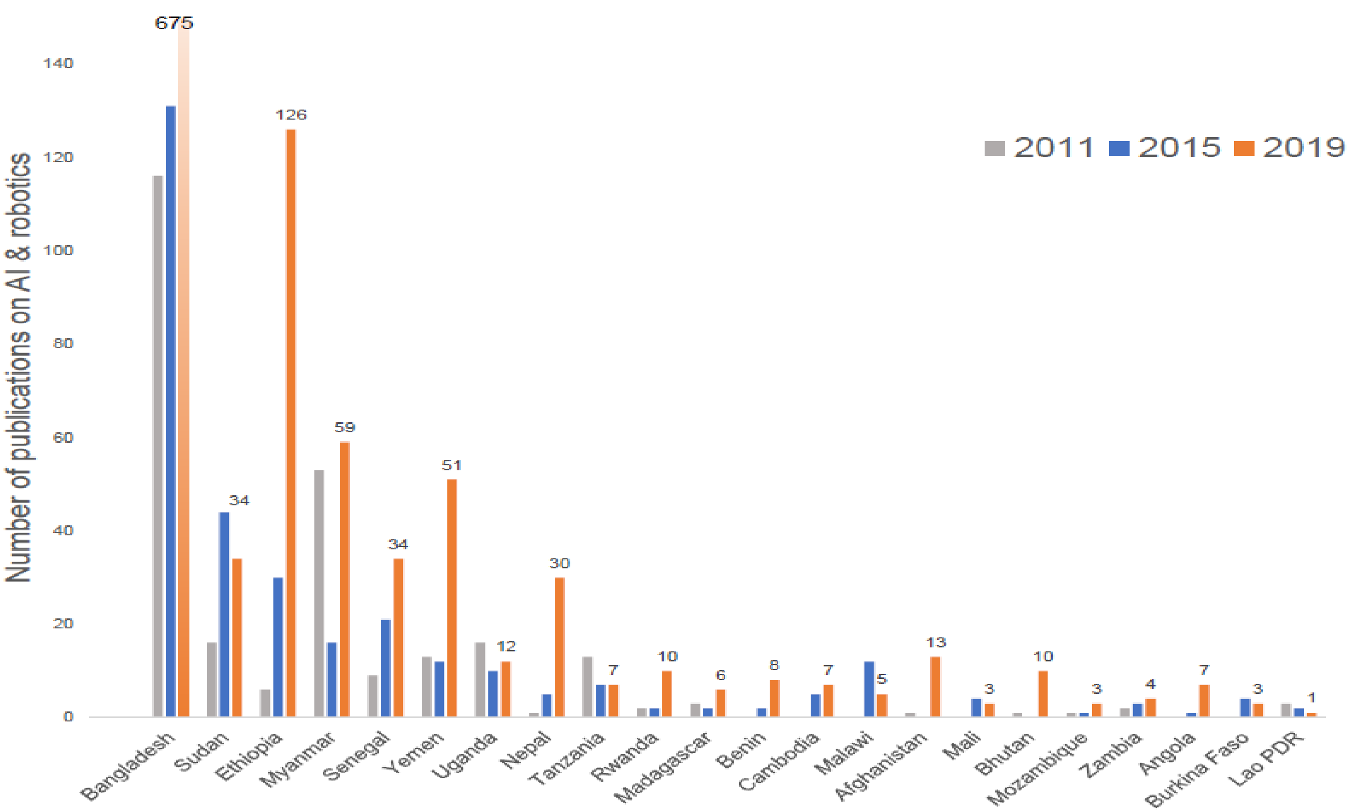


Source: UNESCO Science Report (2021); data from Scopus (Elsevier), excluding Arts, Humanities and Social Sciences, data treatment by Science–Metrix.

The case of Afghanistan demonstrates how much can be achieved in a short space of time with targeted policies and funding (UNESCO, 2021a, 2021b). Afghan scientists produced 285 publications in international journals in 2019, more than four times the number (67) four years earlier. Growth was strongest in the broad field of information and communication technologies (ICTs), mathematics and statistics. Between 2016 and 2019, Afghan scientists produced 187 publications in this field, compared to just seven between 2011 and 2015. By 2019, one-quarter of Afghan scientific publications concerned this field. Strong growth was also observed in research on artificial intelligence (AI) & robotics (Figure 2) and in the field of bioinformatics (Table 1).

What drove these trends? Firstly, research units were installed at 12 Afghan universities over the 2008–2012 period. A digital library was also developed to give students and faculty access to about 9 000 academic journals and 7 000 e-books. For faculty, participating in research became a requirement for promotion. In 2013, research committees established at each of the 12 participating universities began approving research proposals within a competitive bidding process; between 2016 and 2018, the Higher Education Development Project (2015–2020) awarded research grants to 97 development-oriented projects submitted by public and private universities. All of these measures were financed by the Afghanistan Reconstruction Trust Fund administered by the World Bank. In parallel, modern telecommunications infrastructure was installed to enable universities to network with their peers. Meanwhile, private investment in mobile telephony, coupled with a young and technology-savvy population, made telecommunications one of the fastest-growing sectors in Afghanistan. This fostered the emergence of an entrepreneurial ecosystem (UNESCO, 2021b).

Figure 2: Volume of least developed countries' publications on artificial intelligence & robotics, 2011, 2015 and 2019
Data labels are for 2019



NB: The bars for Bangladesh are not drawn to scale.
Source: UNESCO cience Report (2021); data from Scopus (Elsevier), excluding Arts, Humanities and Social Sciences, data treatment by Science–Metrix.

Table 1: Growth in publications by least developed countries on bioinformatics, 2014–2016 and 2017–2019
For countries with at least 10 publications over 2017–2019

	2014–2016	2017–2019
Afghanistan	3	18
Angola	6	10
Bangladesh	456	1 252
Benin	6	17
Bhutan	3	15
Cambodia	7	18
Ethiopia	72	186
Madagascar	8	13
Myanmar	54	138
Nepal	33	71
Rwanda	9	17
Senegal	59	99
Sudan	98	221
Uganda	31	40
Tanzania	22	25

Source: UNESCO Science Report (2021); data from Scopus (Elsevier), excluding Arts, Humanities and Social Sciences, data treatment by Science–Metrix.

In Myanmar, the implementation of economic and democratic reforms between 2011 and 2020 attracted foreign partners for development projects. For example, the Yangoon Innovation Centre was built by the Switzerland-based Seedstars Academy in 2019 and managed by the Yangoon Regional Government. Myanmar enacted its Science, Technology and Innovation Law in 2018 and four laws to protect intellectual property in 2019, including the Patent Law which was to precede the creation of an Intellectual Property Office (Scott-Kemmis et al., 2021). Scientists benefited from a rise in domestic research spending from 0.03% (2017) to 0.15% of GDP (2020), as reported by the UNESCO Institute for Statistics.

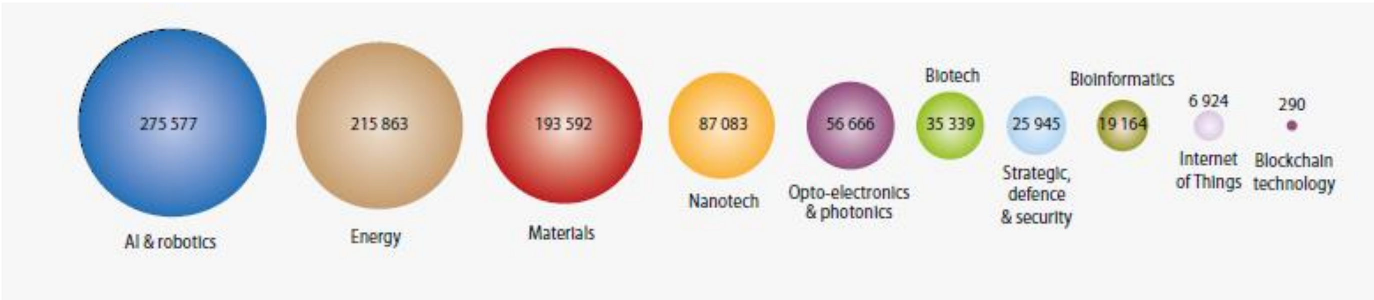
The case studies of Afghanistan and Myanmar reflect the spin-off benefits of reforms that enhance the right to freedom of expression. UNESCO's *Recommendation on Science and Scientific Researchers* (2017) 'details the components of scientific freedom, including autonomy, intellectual freedom, freedom of association, freedom of movement and freedom of expression. Scientific freedom also encompasses the right to publish and the right to protect one's intellectual property rights' (Tash, 2021). An environment that respects scientific freedom also tends to reassure investors.

Growth most visible in cross-cutting strategic technologies

The rapid growth in scientific publishing observed in LDCs includes research on topics considered integral to the Fourth Industrial Revolution. Among the ten sub-fields of cross-cutting strategic technologies studied by the *UNESCO Science Report* (Figure 3), LDCs have markedly increased their research effort in artificial intelligence (AI) & robotics, energy[1], bioinformatics and materials science, particularly since 2015. This mirrors the global trend for the first two technologies (Figures 3 and 4). However, bioinformatics was the third-biggest cross-cutting strategic technology for LDCs but only ranked eighth for volume at global local. This pushed up their world share of bioinformatics research (Figure 5).

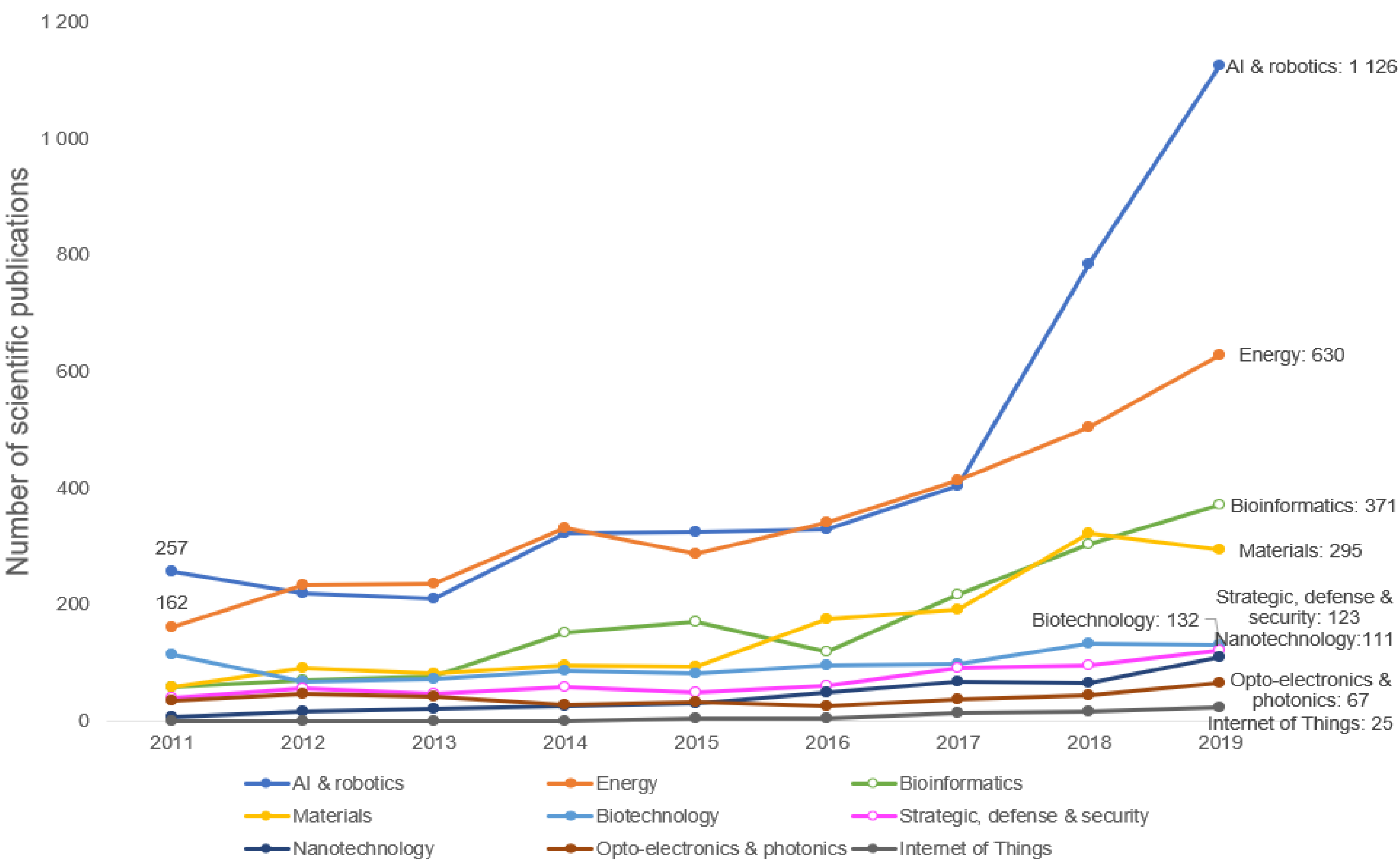
[1] The field of energy research spans fossil fuels, nuclear energy and renewable sources of energy.

Figure 3: Volume of scientific publications worldwide in cross-cutting strategic technologies, 2018–2019



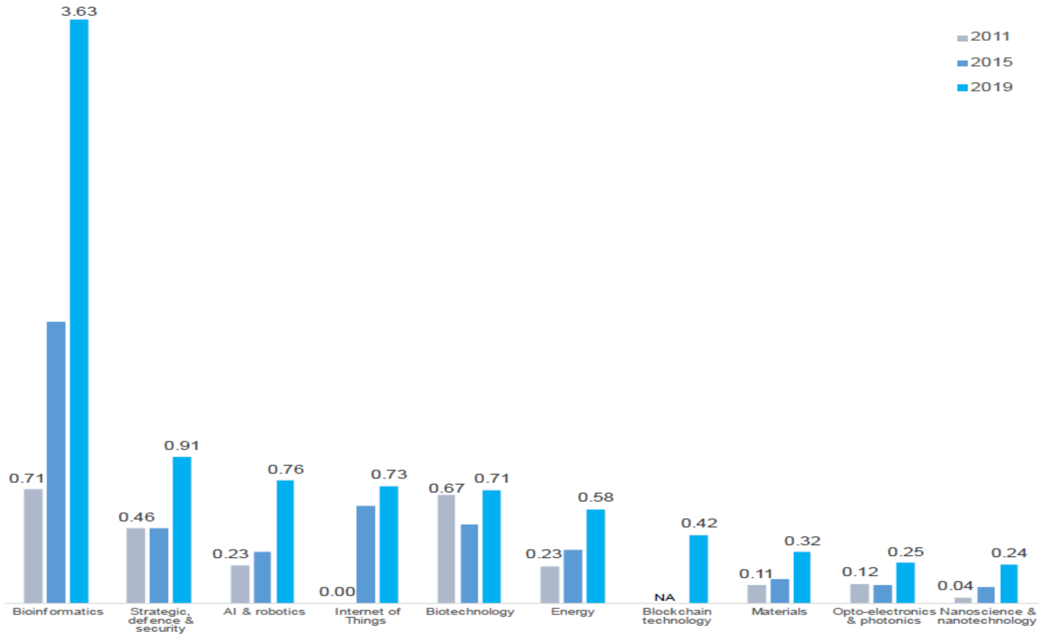
Source: UNESCO Science Report (2021); data from Scopus (Elsevier), excluding Arts, Humanities and Social Sciences, data treatment by Science–Metrix.

Figure 4: Volume of publications on cross-cutting strategic technologies by least developed countries, 2011–2019



Source: UNESCO Science Report (2021); data from Scopus (Elsevier), excluding Arts, Humanities and Social Sciences, data treatment by Science–Metrix.

Figure 5: Least developed countries' world share of cross-cutting strategic technologies, 2011, 2015 and 2019 (%)

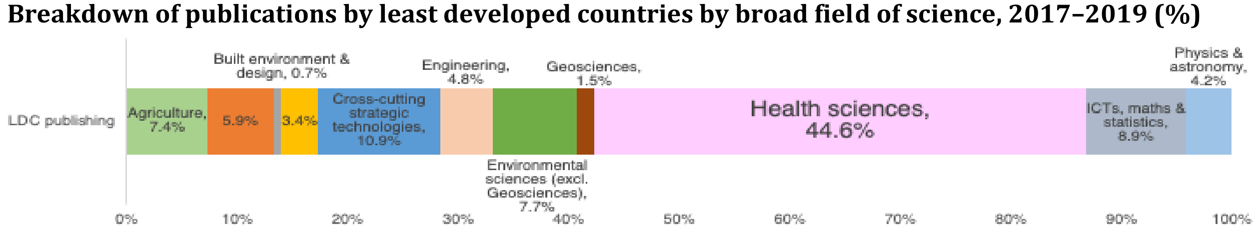


NA: Not applicable; note that the first journals specialized in blockchain technology were launched in 2018

Source: UNESCO Science Report (2021); data from Scopus (Elsevier), excluding Arts, Humanities and Social Sciences, data treatment by Science–Metrix.

Over the 2017–2019 period, cross-cutting strategic technologies accounted for 11% of scientific output by LDCs, their second-highest category after health sciences (Figure 6). The volume of scientific publications on cross-cutting strategic technologies produced by LDCs surged by 166.5% between 2015 and 2019, compared to 33.1% at global level. Pursuit of this trend could have flow-on effects for innovation and entrepreneurship (Schneegans et al., 2021).

Figure 6: Breakdown of publications by least developed countries by broad field of science, 2017–2019 (%)



NB: 5.9% corresponds to animal and plant biology; 3.4% corresponds to chemistry.
Source: UNESCO Science Report (2021); data from Scopus (Elsevier), excluding Arts, Humanities and Social Sciences, data treatment by Science–Metrix.

Recognition that science can accelerate industrialization

LDCs striving to industrialize rapidly recognize that investment in research and innovation can accelerate this process. The African Union aims to create the world's biggest single market for goods and services and customs union with the African Continental Free Trade Area, which has entered its operational phase. Intra-African trade accounted for 14.4% of total African trade in 2018 (AfDB, 2019). For intra-African trade to develop, the continent will need to industrialize and put in place a digital marketplace, since much of future trade may take place on the Internet. To achieve this goal, the business sector will have to play a much bigger role than at present. For instance, the development of infrastructure supporting the digital revolution has been held back by the lack of competition in the business sector, resulting in high costs and low uptake by businesses and consumers, as in Lesotho and Mozambique (Kraemer-Mbula et al., 2021).

Since 2017, Ugandan universities have hosted four centres of excellence within a World Bank project. One of these specializes in materials, product development and nanotechnology, a second in crop investment and a third in pharm-biotechnology and traditional medicine. The University of Rwanda hosts four centres of excellence, including two in data science and the Internet of Things respectively. Rwanda established the East African Institute for Fundamental Research in 2018, which is closely modelled on its partner, UNESCO's Abdus Salam International Centre for Theoretical Physics. Courses given by the Rwandan institute include machine learning and data science (Kingiri and Awono Onana, 2021).

Ethiopia is planning to develop its pharmaceutical sector. *Vision 2050* adopted by the East African Community in 2015 evokes the need to develop R&D in the public sector as the starting point for a viable pharmaceutical industry in the region. Ethiopia devoted 0.3% of GDP to R&D in 2017, according to the UNESCO Institute for Statistics. It has hosted the Africa Centres for Disease Control and Prevention since 2016 and one of its four centres of excellence supported by the World Bank project specializes in innovative drug development and therapeutic trials for Africa (Kingiri and Awono Onana, 2021).

Bangladesh is, by far, the largest exporter of pharmaceutical products among LDCs; the Export Promotion Bureau recorded export earnings of US$ 135.8 million in 2020, almost double the amount six years earlier (US$ 69.2 million). Local firms currently import the raw materials from abroad. Once the Active Pharmaceutical Ingredients Industrial Park at Munshiganj is operational, companies will be able to produce the main chemical components of pharmaceutical drugs themselves; this should lower the cost of domestic drugs and boost their international competitiveness (Osama, Prasad Sha and Wickremasinghe, 2021).

Another priority for Bangladesh is its Digital Bangladesh programme, established in 2011. Initially designed to digitize government services, its focus has expanded over the past decade to include the promotion of social innovation, pro-poor fintech and youth skills. In 2017, it set up an innovation lab (Osama, Prasad Sha and Wickremasinghe, 2021). The most populous LDC, Bangladesh publishes more than any other LDC on cross-cutting strategic technologies.

Some of the countries showing rapid progress in academic publishing despite modest resources benefit from collaboration with their large diaspora, such as in Nepal, Sudan and Yemen. Many of the scientists at Sudanese universities and research centres, for instance, trained at high-ranking universities overseas. These scientists maintain ties with the diaspora through bodies such as the Council of Sudanese Experts and Scientists Abroad (Kingiri and Awono Onana, 2021).

Manufacturing is the most productive sector in Sudan, which also has a comparative advantage in agriculture and agro-processing. The African Development Bank (AfDB, 2018) has suggested that sound policies could help Sudan to position itself as a 'food basket' for its neighbours. Sudan's *Science, Technology and Innovation Policy* adopted in 2017 fixed a target of raising research intensity tenfold to 2% of GDP by 2030. 'Available sources indicate that the government raised research funding by about 30% for the 2018/2019 fiscal year' (Kingiri and Awono Onana, 2021).

Other LDCs have made an effort to invest more in R&D but these gains can prove fragile, such as if the security situation deteriorates. For example, Burkina Faso had raised its research effort to 0.61% of GDP by 2017, one of the highest ratios in Africa, but research budgets subsequently had to be reallocated to fund the security effort (Essegbey et al., 2021). By 2021, Burkina Faso's research effort had recovered to 0.25% of GDP to R&D, according to the UNESCO Institute for Statistics.

Other factors holding back research and innovation in Africa include the lack of venture capital for start-ups and inadequate intellectual property protection. By 2020, the continent counted 744 active tech hubs, according to Briter Bridges. All African LDCs had at least one tech hub and several counted ten or more, including Burkina Faso and Zambia (10 each), Mali (11), Benin and Rwanda (12 each), Angola (17), Uganda (19), Togo (21), Senegal (22) and Tanzania (31). The top fields for African tech hubs were fintech (26%), health (18%), education (17%), agriculture (14%), big data and analytics (8%), software (6%), cleantech (6%) and the digital economy (5%). Many African tech hubs remain dependent on the donor-funded model. CcHub in Nigeria is an exception. This tech hub has adopted a commercial model, charging for workspace and creating its own Growth Capital Fund, Nigeria's first fund targeting social innovation (Essegbey et al., 2021).

The delay in operationalizing the Pan-African Intellectual Property Organization means that the process for registering intellectual property remains costly and difficult to navigate for local inventors. De Andrade and Viswanath (2017) estimate that it costs an African inventor over ten times more than an inventor in the United Kingdom to register and maintain a 30-page patent locally for the first ten years.

Liberia has three tech hubs. Since 2015, the Liberia Innovation Fund for Entrepreneurship (LIFE) has been helping to develop the private sector and create jobs for youth by providing seed funds to industries in the key sub-sectors of textiles, rubberwood and made-in-Liberia products. LIFE is funded jointly by the Governments of Japan and Liberia and managed by the Ministry of Commerce and Industry. A growing interest in innovation led to the enactment of the Liberia Intellectual Property Act in 2016 establishing the Liberia Industrial Property Office (Essegbey et al., 2021).

Innovation hubs are springing up in LDCs in other regions. In Bhutan, for example, the 'Fab Lab' experiment 'is turning into a success story, thanks to the quality of and impact of the projects being developed by young inventors', who are producing digital products and prototypes like mobile phone apps with a social and 'green' orientation. The Fab Lab has been financed by a consortium of foreign donors[2]. Some 40% of resources are used for income-generating activities and the rest is used to give citizens free access to the lab's facilities. Income is generated through membership fees, consultancy services, training workshops and local productions, to cover direct expenses such as salaries, Internet access and rent. The Fab Lab is part of the Fab City Global Initiative, which is creating a network of cities, regions and countries that have pledged to work together to produce everything they consume by 2054 (Elci, 2020).

Conclusions

Academic publishing in least developed countries has made remarkable progress since 2015 but these gains are fragile. They remain vulnerable, for instance, to a deterioration in the national security situation, to backsliding on the rule of law and to curbs on scientific freedom. The 195 signatories of the *UNESCO Recommendation on Science and Scientific Researchers* (2017) include the LDCs. Each LDC has committed to respecting the human right to science and scientific freedom. This means that their researchers 'should be free to express themselves freely and openly, to expound the truth as they see it, to report concerns and exchange with other scientists…Providing these guarantees encourages researchers to risk working in a more open and creative way. Openness and creativity, in turn, have downstream advantages for society by nurturing skills in problem-solving and innovation' (Tash, 2021).

When it comes to publishing on cross-cutting strategic technologies, trends in LDCs reflect the global picture to a certain extent. At both geographical levels, publishing on cross-cutting strategic technologies has grown faster than scientific publishing overall. At both levels, scientific output has been greatest in artificial intelligence & robotics, followed by energy research. However, the third priority for scientists in LDCs has been bioinformatics, whereas this field has been a much lower priority at global level; this explains why the share of LDCs in bioinformatics research has grown so much.

Many tech hubs in LDCs are incubating 'green' and 'digital' products. However, the donor model underpinning these hubs may not prove sustainable in the longer term. Universities in LDCs need support in establishing their own incubators for tech-based start-ups. They can learn from the experience of other developing countries. For example, the University of Campinas (Unicamp) in Brazil launched a technology transfer office in 1989 that has since evolved into an innovation agency. By 2021, some 717 companies had either been founded by alumni or faculty members. Of these spin-offs, over 50 started their development at the university's incubator, Incamp. By 2019, the university had accumulated 1 087 patents, second in volume only to Petrobrás, the giant state-controlled oil company (Chaimovich and Pedrosa, 2021).

In the coming years, one might expect a growing number of governments in LDCs to adopt measures to support their tech start-ups, such as by improving intellectual property protection and empowering their universities to nurture the budding entrepreneurs of tomorrow among their students. This is all the more likely, in that LDCs are industrializing and embarking on the same dual 'green' and digital transition as more developed countries. An empowered, innovative private sector will be vital to this transition.

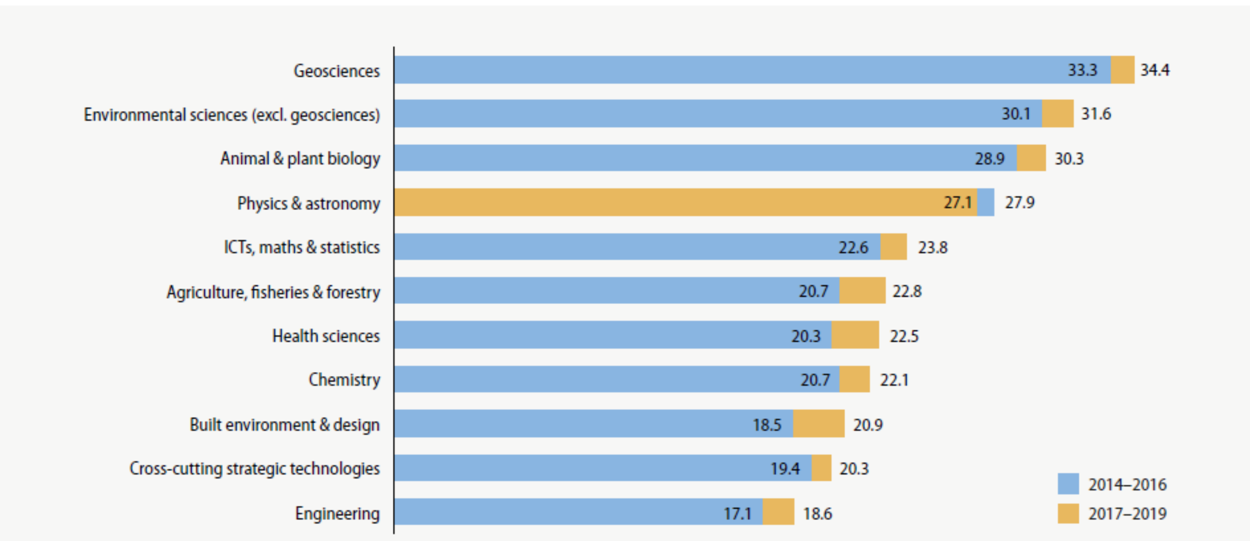
Despite the common 'green' and 'digital' agenda across countries of all income levels, there is a real risk of the technology gap widening. UNCTAD (2023) reports that developing countries' share of global exports of green technologies

[2] Namely, the Center for Bits and Atoms at the Massachusetts Institute of Technology and the SolidWorks Corporation, part of the Dassault Systèmes in France, in collaboration with Keio University in Japan.

fell between 2018 and 2021 from over 48% to under 33%. It suggests that 'technological innovations to address the global climate crisis should increasingly be generated at transnational or even global levels' and that 'more technologically advanced developing countries should step up and strengthen efforts to promote regional and South–South cooperation for green innovation'.

UNESCO has found that the rate of international scientific co-authorship is lowest for cross-cutting strategic technologies (20%) and engineering (19%) [Figure 7]. About 71% of scientific publications from LDCs involved at least one foreign co-author in 2018–2019 but this proportion dropped to 54% for publications on cross-cutting strategic technologies. This suggests a need for greater scientific collaboration with LDCs to develop these technologies. The *Recommendation on Science and Scientific Researchers* states explicitly that openness in the practice of research is necessary to ensure everyone's right to science (Tash, 2021). There is even a roadmap for putting this principle into practice in the form of the *UNESCO Recommendation on Open Science* (2021), which defines a pathway for making scientific information and data more transparent and more accessible to scientists everywhere.

Figure 7: Share of scientific publications involving international collaboration, by broad field, 2014–2016 and 2017–2019 (%)



Source: UNESCO Science Report (2021); data from Scopus (Elsevier), data treatment by Science–Metrix

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