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KEY POINTS

- Frontier technologies have grown significantly in the last two decades and will continue to impact economic and social systems in future
- There is a significant gap between developed and developing countries in terms of preparedness to use, adopt and adapt frontier technologies. Developed countries currently dominate as providers of such technologies and in knowledge generation and trade
- Governments in developing countries need to take proactive action to catch up and close the gap

Moving fast with frontier technologies

In the last two decades, the use of frontier technologies such as artificial intelligence, the Internet of things and energy from renewable sources has undergone significant growth, and this trend is expected to continue. However, there is still considerable concentration in these markets. The leading frontier technology providers are mostly firms from China, the United States of America and a few other developed countries, with little participation from developing countries. The same pattern is observed with regard to knowledge generation and trade. Governments of developing countries should take proactive action to increase preparedness to use, adopt and adapt such technologies and to take up the economic opportunities linked to them. Some of the challenges associated with the adoption of new technologies in developing countries are addressed in this policy brief, and some policy recommendations are proposed.[1]

1 For further information on and analysis of the topics discussed in this policy brief, see UNCTAD, 2023, *Technology and Innovation Report 2023: Opening Green Windows – Technological Opportunities for a Low-Carbon World* (United Nations publication, Sales No. E.22.II.D.53, Geneva), available at https://unctad.org/publication/technology-and-innovation-report-2023.

Frontier technologies: A rapidly expanding market

UNCTAD, in *Technology and Innovation Report 2023*, examines 17 frontier technologies, defined as new and rapidly developing technologies that take advantage of digitalization and connectivity, which are divided into three broad categories (figure 1). The categories overlap; for example, the strategic use of drones might have a positive impact on climate change mitigation as their use can help in the reduction of greenhouse gas emissions given lower levels of energy consumption per package delivery compared with the use of vehicles, and the use of nanotechnology can help improve the use of renewable sources of energy.[2] Together, these technologies might represent a market of up to $9.5 trillion in 2030, a sixfold increase compared with their market size of $1.5 trillion in 2020. Besides this market expansion, these technologies are also expected to lead to the creation of new jobs and trade expansion. For example, the global value chain of fifth-generation technology is expected to support 22 million jobs by 2035, and 3.3 million direct jobs are expected to be created in the wind energy sector by 2025.[3] With regard to trade, for example, exports of electric vehicles by the leading 15 exporter countries increased by more than threefold in 2018–2021, from $28 billion to $105 billion.

Figure 1
Frontier technologies

Industry 4.0	Green	Other
Artificial intelligence	Solar photovoltaics	Nanotechnology
Internet of things	Concentrated solar power	Gene editing
Big data	Biofuels	
Blockchain technology	Biogas and biomass	
Fifth-generation technology	Wind energy	
Three-dimensional printing	Green hydrogen	
Robotics	Electric vehicles	
Drone technology		

Source: UNCTAD, 2023.

The gap between developed and developing countries

Despite the rapid expansion of frontier technologies and the upward growth trend, this growth is not taking place equally among developed and developing countries. With regard to green technologies, for example, in 2018–2021, the total exports of developed countries grew from around $60 billion to $156 billion (increasing by a factor of 2.6) and imports increased from $89 billion to $188 billion, while the total exports of developing countries grew from $57 billion to $75 billion (increasing by a factor of 1.3) and imports increased from $48 billion to $63 billion.

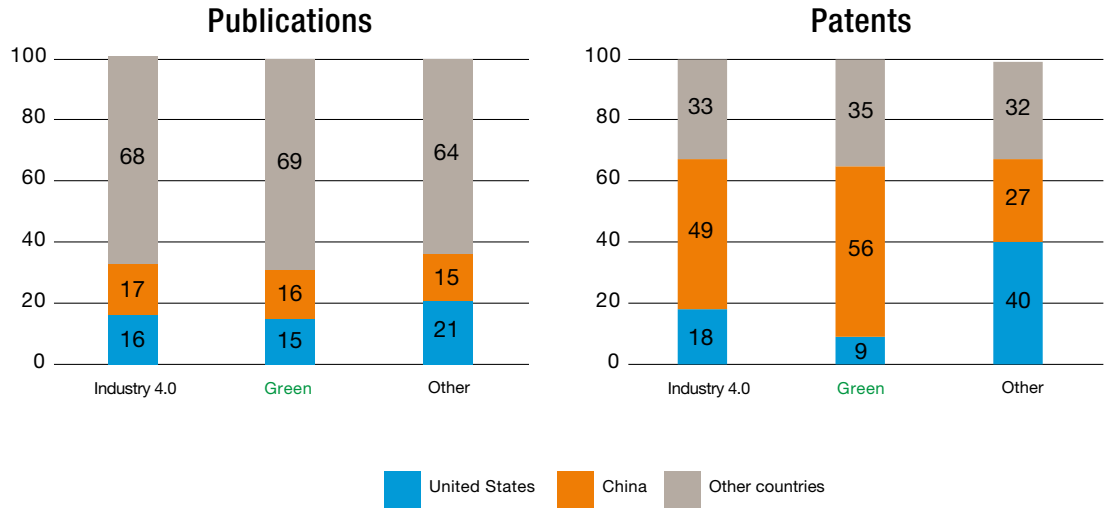
The market of frontier technologies is supplied primarily by a few countries, notably China, the United States and countries in Western Europe. The leading providers of the 17 frontier technologies examined in Technology and Innovation Report 2023 were in these countries, except for two companies from developing countries; one from among the leading suppliers of biofuels and one in the biogas and biomass sector.

There is a similar pattern of concentration in knowledge generation. Publications and patents related to frontier technologies are largely concentrated in China and the United States, which together account for around 30 per cent of global publications and almost 70 per cent of patents in each technology category (figure 2).

2 Ahmadi MH, Ghazvini M, Nazari MA, Ahmadi MA, Pourfayaz F, Lorenzini G and Ming T, 2019, Renewable energy harvesting with the application of nanotechnology: A review, *International Journal of Energy Research*, 43(4)1387–1410; Hussein AK, 2015, Applications of nanotechnology in renewable energies: A comprehensive overview and understanding, *Renewable and Sustainable Energy Reviews*, 42(C):460–476; Rodrigues TA, Patrikar J, Oliveira NL, Scott Matthews H, Scherer S and Samaras C, 2022, Drone flight data reveal energy and greenhouse gas emissions savings for very small package delivery, *Patterns*, 3(8); Zang L, ed., 2011, *Energy Efficiency and Renewable Energy Through Nanotechnology*, Springer, London.

3 See https://cdn.ihs.com/www/pdf/IHS-Technology-5G-Economic-Impact-Study.pdf and https://gwec.net/wind-can-power-over-3-3-million-jobs-over-the-next-five-years/.

Figure 2
Shares of publications and patents by frontier technology category: China, the United States and other countries



Source: UNCTAD calculations, based on data from Scopus (publications) and the Patent Search and Analysis Database (patents).

Preparedness among countries to use, adopt and adapt frontier technologies reflects these disparities. The following five dimensions are considered under the UNCTAD frontier technology readiness index in order to assess such preparedness: information and communications technology (ICT) deployment; skills; research and development activity; industry activity; and financial access.[4] The assessment in 2023 considered 166 economies, ranked according to readiness level. The ranking is dominated by high-income countries, led by the United States and followed by Sweden, Singapore, Switzerland and the Kingdom of the Netherlands. Emerging economies are primarily found in the second quarter of the list, and countries in Latin America and the Caribbean and sub-Saharan Africa are among the least ready to use, adopt and adapt frontier technologies. Having a low index score suggests a lack of the foundational capacity required to take full advantage of the economic opportunities linked to frontier technologies.

Some developing countries have moved up the ranking or ranked higher than expected due to policies and incentives in place. For example, Brazil, following improvements in ICT development, has moved up the ranking compared with in 2021. Other countries ranked higher than expected according to estimated rankings based on gross domestic product per capita, in particular the following: India, which ranked 67 positions higher than estimated, reflecting achievements related to research and development and ICT, as well as the significant availability of skilled human capital at relatively low costs; the Philippines, which ranked 54 positions higher; and Viet Nam, which ranked 44 positions higher. The Philippines and Viet Nam have a high ranking in industry, with significant foreign direct investment in high-technology manufacturing.

Policy recommendations

In order to capture the economic gains associated with frontier technologies, firms in developing countries need to have the required capabilities to enter new and growing sectors. Governments need to establish the necessary policies, regulations and infrastructure to support these firms. Important measures in this regard include the following:

- **Promote investments in ICT infrastructure.** To take advantage of frontier technologies, countries should develop the required infrastructure. For example, digital technologies often require high-speed and high-quality Internet connections, and there are significant inequalities in this regard both between and within countries. Achieving the desired development level requires both public and private investment in ICT infrastructure, along with governmental

4 UNCTAD, 2021, *Technology and Innovation Report 2021: Catching Technological Waves – Innovation with Equity* (United Nations publication, Sales No. E.21.II.D.8, Geneva).

measures to address and avoid connectivity disparities between small and large firms and between rural and urban areas

- **Invest in human capital.** Countries should ensure that the labour force has the required skills to use and develop frontier technologies. Dedicated training programmes may be necessary to build local specialized, technological, managerial and organizational capabilities, along with learning-by-doing and on-the-job training. For example, in China, in the biomass sector, State-owned design institutes diffuse technical knowledge, there is regulation to ensure that they are involved when biomass power plants are constructed and such institutes often learn from pioneer companies then disseminate the knowledge to others; in Thailand, specialized training takes places through universities and research centres[5]
- **Narrow the knowledge gap.** New technologies, especially those that are less mature, tend to require greater levels of research and development. Governments can offer subsidies to build up research, with collaboration from industry and academia, both domestic and foreign. For example, in China, firms are encouraged to carry out research related to solar photovoltaics with international partners, to access external knowledge; in Oman, Innovation Park Muscat, an initiative under the Ministry of Higher Education, Research and Innovation, supports research, innovation and collaboration between sectors[6]
- **Ensure the availability of finance.** Governments should act to ensure the availability of the necessary funds to incentivize frontier technologies, such as through governmental programmes and public institutions such as development banks. For example, in China, the development bank and other State and commercial banks provided credit to producers of photovoltaics at a time when other companies in developed countries had difficulty accessing credit due to the financial crisis in 2009.[7] External finance and support from the international community can also play a role. For example, in Morocco, concentrated solar power installations have been supported by the African Development Bank, European Union financing institutions and the World Bank as well as the Climate Investment Funds[8]
- **Incentivize and promote an enabling environment to support targeted technologies.** A high score on the frontier technology readiness index does not necessarily mean that a country will be able to generate and reap the economic benefits associated with frontier technologies. Governments also need to implement appropriate policies and investments. For example, in China, in 2006, a renewable energy law stimulated the initial development of the biomass industry; in Egypt, in 2014, a renewable energy law prompted an increase in the production of renewable energy by the private sector[9]

5 Hansen T and Hansen UE, 2020, How many firms benefit from a window of opportunity? Knowledge spillovers, industry characteristics and catching up in the Chinese biomass power plant industry, *Industrial and Corporate Change*, 29(5):1211–1232; Suwanasri K, Trakulvichean S, Grudloyma U, Songkasiri W, Commins T, Chaiprasert P and Tanticharoen M, 2015, Biogas: Key success factors for promotion in Thailand, *Journal of Sustainable Energy and Environment* (special issue):25–30.

6 Shubbak MH, 2019, The technological system of production and innovation: The case of photovoltaic technology in China, *Research Policy*, 48(4):993–1015; Oman, 2022, Statement at Commission on Science and Technology for Development 2022–2023 intersessional panel meeting, available at https://unctad.org/meeting/cstd-2022-2023-inter-sessional-panel.

7 Shubbak, 2019.

8 See https://www.worldbank.org/en/news/feature/2016/11/08/learning-from-morocco-why-invest-in-concentrated-solar-power.

9 Iizuka M, 2015, Diverse and uneven pathways towards transition to low carbon development: The case of solar photovoltaic technology in China, *Innovation and Development*, 5(2):241–261; Egypt, 2022, Statement at Commission on Science and Technology for Development 2022–2023 intersessional panel meeting, available at https://unctad.org/meeting/cstd-2022-2023-inter-sessional-panel.

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