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Issue Paper
On
Diversifying economies in a world of accelerated digitalization

Unedited Draft

Prepared by the UNCTAD Secretariat[1]

[1] Contributions from the Governments of Austria, Belize, Brazil, Cuba, Ecuador, Gambia, Germany, Indonesia, the Islamic Republic of Iran, Latvia, Peru, the Philippines, Poland, Portugal, Russian Federation, Switzerland, Türkiye, United Kingdom, and Zambia, as well as the Economic and Social Commission for Asia and the Pacific (ESCAP), and Economic and Social Commission for Western Asia (ESCWA), International Telecommunication Union (ITU), Office of the UN Secretary-General's Envoy on Technology (OSET), Organisation for Economic Co-operation and Development (OECD), United Nations Technology Bank for Least Developed Countries (UNTBLDC), and World Intellectual Property Organization (WIPO) are gratefully acknowledged.

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I. Introduction

At its twenty-seventh session held in April 2024, the United Nations Commission on Science and Technology for Development (CSTD) selected “Diversifying economies in a world of accelerated digitalization” as one of its two priority themes for the 2024-2025 inter-sessional period. To contribute to a better understanding of this theme and to assist the Commission in its deliberations at its twenty-eighth session, the Commission secretariat has prepared this issue paper based on relevant literature and case studies contributed by Commission members and international organizations.

Economic diversification is an essential component of economic development and a key area of Sustainable Development Goal (SDG) 9, which aims at enhancing scientific research and upgrading technological capabilities of industrial sectors through innovation, particularly in developing countries. Indeed, economic diversification is strongly associated with income growth. It is only at relatively high levels of per capita income that specialization takes over as a dominant economic force (Imbs and Wacziarg, 2003). Economic diversification reflects the reallocation of resources over a range of productive activities, leading to a structural transformation of the economies. Yet, many developing countries are still classified as commodity dependent.

The Bridgetown Covenant adopted by UNCTAD’s 195 member States[2] highlights the need to transform the economies through economic diversification not only to sustain economic growth, but also to increase resilience to external shocks, and to benefit from technological change and the increasing digitalization of the world economy. The accelerated pace of digitalization boosted by continuous technological advancements is one of the megatrends that has reshaped the way people produce, work, interact and live. For instance, internet penetration has almost doubled in the past decade to cover around two-thirds of the world population in 2023.[3] Smartphone adoption has also surged, with over half of the global population owning a smartphone.[4] The rapid digitalization has significantly increased access to digital services and platforms, transforming both global value chains (GVCs) and economic diversification.

The accelerated digitalization introduces both new opportunities and challenges to developing countries in terms of economic diversification. On the one hand, it opens new avenues to enhance productivity, develop new industries, and empower small and medium size enterprises (SMEs) to catch up and innovate. On the other hand, existing digital divides, such as infrastructure deficits and lack of digital literacy, makes it difficult for developing countries to upgrade their industrial ecosystems and compete with developed countries.

The “Pact for the Future”, adopted by UN member States in September 2024, further emphasizes the importance of international cooperation to harness the benefits of science, technology and innovation while bridging the growing divide within and between countries. In this respect, the Global Digital Compact therein sets a series of commitments to ensure that digital technologies will contribute to sustainable development and human rights. It includes among its objectives the enhancement of international governance of artificial intelligence for

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[2] https://unctad.org/system/files/official-document/td541add2_en.pdf
[3] https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx
[4] https://www.gsma.com/newsroom/press-release/smartphone-owners-are-now-the-global-majority-new-gsma-report-reveals/

the benefit of humanity.[5]

In this regard, this paper explores strategies for diversifying economies in an era of rapid digitalization, with a focus on supporting policymakers in developing countries to design responsive policies that capitalize on the benefits provided by frontier digital technologies, thereby increasing productive capacities and resulting in diversified industries with higher value-added production that benefit all sectors of society.

The paper is structured as follows. Section II discusses the opportunities and challenges for economic diversification brought by Industry 4.0 technologies. Section III examines how industrial, and innovation policies should be revamped in the digital era to drive technology-led structural transformation and industrial upgrading. Section IV analyses the readiness of countries to leverage digitalization to diversify their economies, in terms of three key areas: infrastructure, data, and skills. Section V explores how international cooperation, including digital public infrastructure and open innovation approaches, can support less technologically advanced developing countries to catch up with rapid technological change. Section VI concludes and provides recommendations for the consideration of Member States, the international community, and the CSTD. In the annex, the paper includes a list of suggested questions to facilitate the dialogue at the Intersessional Panel of the CSTD in October 2024.

[5] https://www.un.org/en/summit-of-the-future/pact-for-the-future

II. Opportunities and challenges for economic diversification in the digital era

Economic development involves a process of structural transformation which consists in the reallocation of economic activities from relatively simple to increasingly diversified and complex productions, which require more knowledge-intensive inputs and generate higher value-added outputs. Through economic diversification, a country expands its economic activities to new sectors or products, either across industries (e.g., from agriculture to manufacturing or services) or within industries (e.g., moving toward more complex productions in an industrial value chain). Economic diversification posits the reduction of the dependence on few activities by promoting growth in other areas to differentiate production on a range of valuable goods and services, increase productivity and income. It is therefore a cornerstone for building more sustainable and resilient economies, leading to employment creation and economic growth.[6]

It is well known that an excessive dependence on a few commodities or sectors makes a country vulnerable to price fluctuations and global shocks, such as the COVID-19 pandemic and the climate crisis, and is more generally associated with lower productivity and human well-being. Empirical evidence shows that export diversification positively impacts per capita income growth in developing countries.[7] Yet, a staggering 85 per cent of the world's least developed countries are considered commodity dependent (i.e., with at least 60 per cent of their total merchandise export revenues from commodity exports), compared to only 13 per cent of advanced economies (Figure 1). Moreover, estimates show that under the current conditions the average commodity-dependent country would need 190 years just to cut in half their dependence compared with other nations.[8]

Economic diversification is a path-dependent process, where new economic activities exploit capacities previously developed for other activities, thus the mix of goods that a country produces may have important implications for economic growth (Hausmann et al., 2007). In developed countries, diversification is mostly the result of frontiers technologies and innovation, which lead to the emergence of new industries. In developing countries, diversification is often a process of emulation where countries learn from the diversification paths of their counterparts with similar characteristics (e.g., natural resources, capital, and labour) but with higher income per capita or technological capacities (Kojima, 2000). Activities most likely to be emulated typically involve technologies that closely align with those used in the economy's current activities. For instance, the production of digital good and services relies on technologies that can serve as foundational elements in various sectors, while primary products generally involve technologies that offer limited opportunities in other sectors, making diversification challenging.

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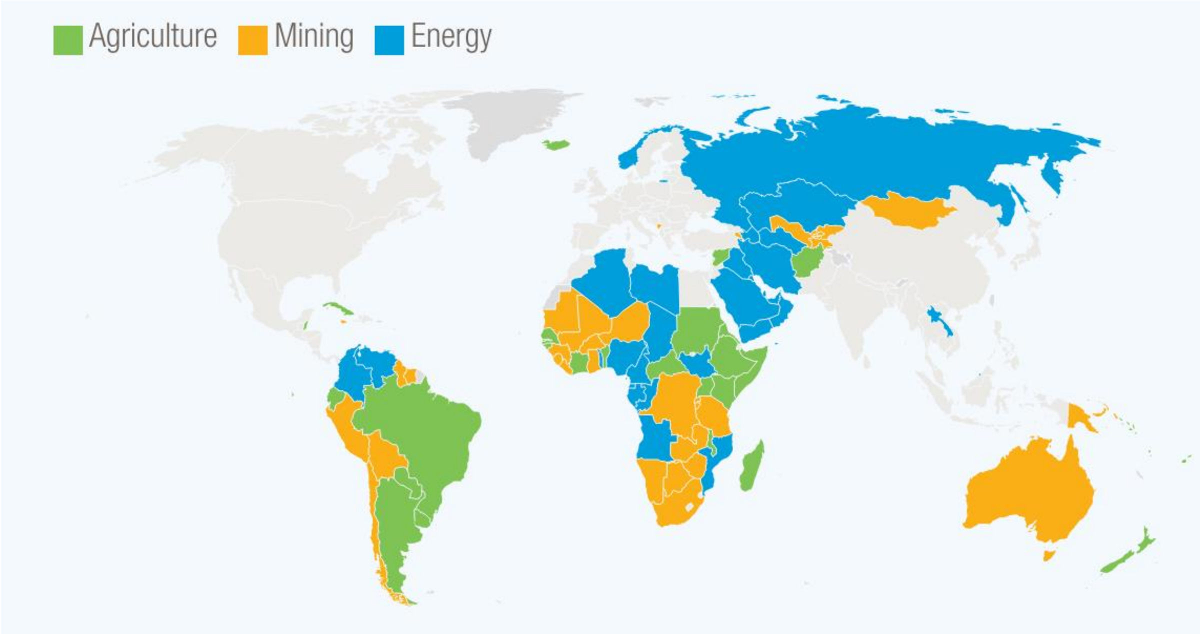
6 https://www.tandfonline.com/doi/full/10.1080/09638199.2011.619009; https://documents.worldbank.org/pt/publication/documents-reports/documentdetail/821641468323336000/breaking-into-new-markets-emerging-lessons-for-export-diversification

7 https://documents.worldbank.org/en/publication/documents-reports/documentdetail/577921468150573677/export-diversification-and-economic-growth

8 https://unctad.org/news/commodity-dependence-5-things-you-need-know

Figure 1: Commodity-dependent countries and their main dependency, 2019–2021

(countries with commodity exports representing at least 60% of total merchandise export revenues)



Source: UNCTAD calculations based on UNCTADstat.
Note: In the case of two countries (Togo and United Arab Emirates), it was not possible to consistently identify the dominant commodity group due to the presence of large volumes of exports of manufactured products that may partially or totally be re-exports. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Endogenous growth theory emphasizes the role of human capital and knowledge spillovers effects, thus giving momentum to the concept of economic diversification and dynamic returns (Lucas Jr, 1988).[9] The increasing importance of productive knowledge and knowledge spillovers are reflected in current theories of economic complexity highlighting that larger amounts of productive knowledge require increasingly complex webs of human interactions (Hidalgo and Hausmann, 2009). Why is this relevant for science, technology and innovation (STI) and economic diversification? Because technology is essentially embodied (artifacts), codified (e.g., patents) and tacit (e.g., experience) knowledge and the way it is combined to create new more sophisticated goods and services is key for economic diversification and growth. The higher the set of productive capabilities (knowledge) the higher the probability a country can produce new sophisticated good and services,[10] which reflected in a faster pace of structural transformation. Figure 2 shows that the structural transformation pillar of UNCTAD's productive capacities index takes higher values for countries at a higher level of development. This confirms that development is associated with economic diversification, production complexity and high shares of manufacturing and services value added (the main components of the structural transformation pillar). A key question for economic diversification is how to acquire new productive knowledge to upgrade the productive base.

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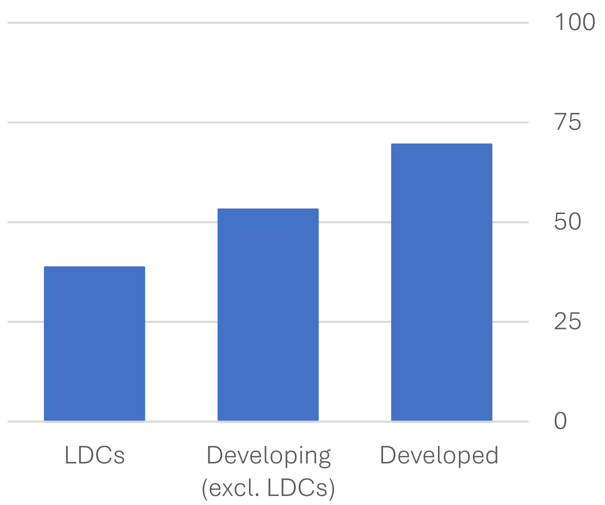
[9] Lucas's work was inspired by Jane Jacobs; she pointed out that most of economic life is creative, but it is left out from the economic theory of production (Jacobs, 1969).
[10] https://growthlab.hks.harvard.edu/files/growthlab/files/atlas_2013_part1.pdf

The Economic Complexity Index (ECI), developed by economists Ricardo Hausmann and César Hidalgo, is a metric that quantifies the amount of knowledge and capabilities embedded in the productive structure of an economy.[12] The index reflects how diverse and complex an economy is by weighting positively the diversity of its exports and negatively the ubiquity of the goods exported. Because few countries have the capabilities to stay at the technological frontier and produce the most complex products, less ubiquitous products tend to be also the most complex ones. The concept of economic complexity posits that countries are more likely to develop and export a product that is close to the products that it already exports. Existing technological and productive capabilities shape diversification opportunities, and development is associated with diversification into products with higher-than-average complexity within the country.

Figure 2: Structural transformation score



Source: UNCTADStat, structural transformation pillar of the productive capacities index.[11]
Note: The chart reports the median group value for 2021.

Compared to the conventional growth-related indicators, such as years of schooling or credit to gross domestic product (GDP) ratio, studies show that ECI has a higher explanatory and predictive power on economic growth (Hidalgo and Hausmann, 2009). This confirms that the creation of the conditions necessary for complexity to emerge is a key element of development and can foster sustained growth and prosperity. And additional consideration is that more complex economies tend to have lower levels of income inequality also once controlling for GDP per capita (Ferraz et al., 2021).

A. From export-oriented industrialization to technology-led transformation

Rapid technological change and digitalization are two key trends that are changing the context in which developing countries need to learn and build capabilities, and which require new approaches to innovation and industrial development.[13]

Changes in global markets, technological advancements, and policy shifts contribute to the emergence of new opportunities for economic diversification. In a world of accelerated digitalization technology-led transformation is becoming a kay factor for economic diversification and industrial upgrading that require a rethinking of traditional import-substituting and export-oriented approaches.

[11] For more information about the index, see: https://unctad.org/topic/least-developed-countries/productive-capacities-index
[12] https://atlas.cid.harvard.edu/
[13] https://unctad.org/publication/framework-science-technology-and-innovation-policy-reviews

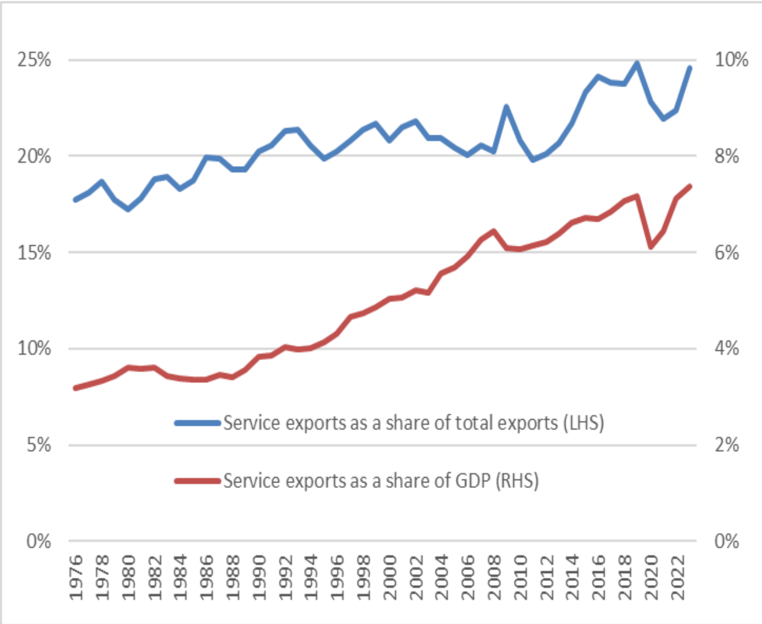
The advent of information and communication technologies (ICT) brought cheaper and more reliable telecommunications that made it easier for manufacturing firms to outsource and coordinate their activities globally. This, coupled with falling transport costs and further pushes toward trade liberalization, favoured globalization and the emergence of GVCs oriented models for development. Joining GVCs is seen as a main vehicle for promoting economic growth and diversification through learning-by-exporting and upgrading as it allows developing countries to specialize in niches within larger global industries.

However, the diffusion of technology and upgrading along the value chain are subject to various preconditions. The GDP contribution of GVCs participation may be limited if countries capture only a small share of the value added generated within the chain.[14] More importantly, the benefits from participating in GVCs have been undermined by premature deindustrialization in developing countries (i.e., a decline in the manufacturing sector at an earlier stage of economic development and a lower peak level of industrialization than the historical norms) due to a skill- and capital-biased technological change that increased labour productivity in advanced economies but undercut the comparative advantage of low-cost labour in developing economies. As a result, it has become more difficult for developing countries to replicate the manufacturing success stories of previous decades.[15]

These trends gave rise to concepts such as the third industrial revolution or the knowledge-based economy, which emphasizes the key role of knowledge-intensive activities (Foray, 2006).[16] Innovation and value creation are increasingly happening in the knowledge-intensive services sectors, making the services sector more important in terms of both exports and outputs (Figure 3). This, along with labour-saving technological change, has reduced the job-creation potential of manufacturing sectors, both in developing and advanced economies. Particularly in developing countries, this is related to an existing dichotomy between large and small firms that limit aggregate jobs and productivity growth. Large firms exhibit higher productivity but do not expand employment, while small firms, the one absorbing employment, do not experience productivity growth.[17]

[14] https://unctad.org/system/files/official-document/wir2013_en.pdf
[15] https://drodrik.scholar.harvard.edu/files/dani-rodrik/files/premature_deindustrialization.pdf
[16] https://mitpress.mit.edu/9780262562232/the-economics-of-knowledge/; https://www.econstor.eu/bitstream/10419/95060/1/wp256.pdf
[17] https://www.nber.org/system/files/working_papers/w28344/w28344.pdf

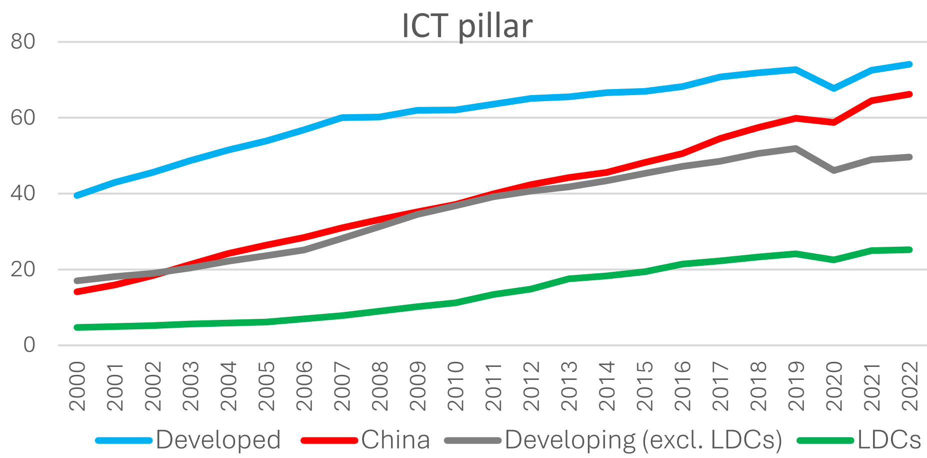
Figure 3: The increasing importance of service exports



Source: UNCTAD elaborations on World Bank data.

Moreover, the profound transformation of many markets for goods and services and the specific economics of production with near zero marginal costs have led to the emergence and dominance of digital platforms whose business model emphasizes the monetization of data.[18] This shift has created numerous new economic opportunities, including around e-commerce and the data value chain, and highlighted the importance of digital-driven innovation as an economic growth engine. However, developed countries have higher ICT capabilities than developing countries and LDCs. Figure 4 reports median value for the ICT pillar of the UNCTAD's productive capacities index, suggesting there are no signs that gaps in internet penetration, fixed broadband availability or availability of secure servers are closing.

Figure 4: Gaps in ICT across country groups are not closing



Source: UNCTADStat, ICT pillar of the productive capacities index.
Note: The chart reports the median group value.

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[18] https://unctad.org/publication/digital-economy-report-2019

Against this backdrop, it is important to consider technological change and the way it impacts both global markets and the local economy to understand options for industrial upgrading and successful economic diversification. As the global economy shifts toward services, we need an industrial policy framework that supports the growth and development of modern economic activities in a broader sense, extending beyond just manufacturing.[19] Industrial policies increasingly need to consider their role in supporting the adoption and development of new technologies as well as the creation, dissemination and absorption of productive knowledge. In other words, supporting the development of a strong STI system for a technology-led diversification and addressing the shift in value creation towards knowledge and digitalization are two key aspects of modern industrial policies.[20]

B. Digitalization and opportunities for economic diversification

The digital revolution and recent technological advancements in ICT lead to the emergence of a series of frontier technologies that sparked a Fourth Industrial Revolution, the so-called Industry 4.0 technologies. These includes artificial intelligence (AI), internet of things (IoT), big data, blockchain, 5G, 3D printing, robotics and drone technology.[21] The term “fourth industrial revolution” denotes the integration of digital and physical systems that multiplies the quantity of devices connected and amount of information produced, which makes data and connectivity a key element for competitiveness. Moreover, the use of Industry 4.0 technologies can unlock new forms of interaction between humans and machines to optimize production processes. The recent breakthroughs in AI brought by Generative AI (GenAI) further offer opportunities for an effective human-robot collaboration based on intelligent machines that will augment workers’ skills, thereby transforming work and reinventing business. Table 1 provides a brief description of Industry 4.0 technologies.

Table 1: A brief description of Industry 4.0 technologies

Technology	Description
Artificial intelligence (AI)	AI is normally defined as the capability of a machine to engage in cognitive activities typically performed by the human brain. AI implementations that focus on narrow tasks are widely available today, used for example, for virtual assistants in smartphones, and for spotting spam or detecting credit card fraud.
Internet of things (IoT)	IoT refers to internet-enabled physical devices that collect, share, and act based on data. There are a vast number of potential applications. Typical fields include wearable devices, smart homes, smart cities, and industrial automation. In manufacturing, IoT connects traditional machinery and tools with actuators and sensors.

[19] https://link.springer.com/article/10.1007/s10842-019-00322-3

[20] https://www.wipo.int/edocs/pubdocs/en/wipo-pub-944-2024-en-world-intellectual-property-report-2024.pdf

[21] The UNCTAD’s 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: (i) Industry 4.0 frontier technologies which include artificial intelligence (AI), Internet of things (IoT), big data, blockchain, 5G, 3D printing, robotics and drone technology, (ii) green frontier technologies which encompass solar photovoltaics, concentrated solar power, biofuels, biogas and biomass, wind energy, green hydrogen and electric vehicles, and (iii) other frontier technologies which comprehend nanotechnology and gene editing. https://unctad.org/system/files/official-document/tir2023_en.pdf

Big data	Big data refers to datasets whose size or type is beyond the ability of traditional database structures to capture, manage, and process. Big data also refers to the used of traditionally inaccessible or unusable data for making decisions.
Blockchain	A blockchain refers to an immutable time-stamped series of data records supervised by a cluster of computers not owned by any single entity. Blockchain serves as the base technology for cryptocurrencies, enabling peer-to-peer transactions that are open, secure, and fast.
5G	5G networks are the next generation of mobile internet connectivity, offering download speeds of around 1-10 Gbps (4G is around 100 Mbps) as well as more reliable connections on smartphones and other devices.
3D printing	3D printing, also known as additive manufacturing, produces three-dimensional objects based on a digital file. 3D printing can create complex objects using less material than traditional manufacturing. 3D printers are used for prototyping and also for final production in manufacturing.
Robotics	Robots are programmable machines that can carry out actions and interact with the environment via sensors and actuators, either autonomously or semi-autonomously. They can take many forms: disaster response robots, consumer robots, industrial robots, military/security robots, and autonomous vehicles.
Drones	A drone, also known as an unmanned aerial vehicle (UAV) or unmanned aircraft system (UAS), is a flying robot that can be remotely controlled or fly autonomously using software with sensors and GPS. Drones have often been used for military purposes, but they also have civilian uses such as in videography, agriculture, and in delivery services.

Source: UNCTAD (2023).[22]

While there has been a proliferation of AI applications in different sectors in recent years, ranging from agriculture, manufacturing, healthcare, education, transportation and public administration,[23] the growing capabilities and adaptability of new algorithms signify a paradigm shift that is transforming AI into a general-purpose technology that augments other Industry 4.0 technologies.[24] For example, Artificial Intelligence of Things (AIoT) represents the fusion of AI and IoT and one significant application is the development of smart factory in the manufacturing sector.[25] This, combined with 5G networks supporting a much higher number of connections and data transmission with high speeds and low latency, can lead to intelligent connectivity and enable new transformational capabilities in many industries.[26]

[22] https://unctad.org/system/files/official-document/tir2023_en.pdf
[23] Contributions from the Governments of Brazil, Cuba, Iran, Latvia, Peru, the Philippines, Poland, Portugal, Türkiye and Zambia, as well as ESCAP, ESCWA, ITU and WIPO.
[24] https://arxiv.org/ftp/arxiv/papers/2308/2308.02558.pdf
[25] https://www.sap.com/uk/products/scm/what-is-a-smart-factory.html
[26] https://www.amazon.com/Intelligent-Connectivity-AI-IoT-5G/dp/1119685184; https://www.huawei.com/en/huaweitech/publication/winwin/33/intelligent-connectivity-the-fusion-of-5gaiiot#:~:text=What%20is%20Intelligent%20Connectivity%3F,Internet%20of%20Things%20(IoT)

The importance of knowledge and Industry 4.0 technologies for economic diversification and sustainable growth can be illustrated with the "Scrabble metaphor". The economy can be considered as a game of Scrabble, where each country has a set of productive capabilities (letter tiles) to make products (words). Words (products) are meaningful combinations of letters, and longer words correspond to more complex products.[27] Industry 4.0 technologies can be seen as blank tiles (or wild cards) that can be used as any letter to make new words, thus increasing the number of letter available to form longer words (complex products).

Photo by Marcus Winkler (CC)

While each technology has its specific applications, Industry 4.0 technologies share some common features that are applicable across sectors, including advanced automation that optimizes processes with minimal human intervention, data-driven decision making that leads to more efficient and accurate operations, seamless digital connection that facilitates interaction between human and machines, and high flexibility that supports mass customization. These key features could significantly support developing countries in diversifying their economies through three channels: (i) enhancing productivity, (ii) fostering new industries, and (iii) promoting digital and green transition.

1. Enhancing productivity

Higher productivity boosts the international competitiveness of firms and products, driving export growth and fostering economic diversification in the presence of economies of scope, or when increased productivity for one product is translated in lower cost producing other products locally. Increased competitiveness can also attract foreign investment across a wide range of industries and generate surplus profits that can be reinvested in new activities and products, thus promoting diversification.

Empirical evidence shows that developing countries actively engaged with Industry 4.0 technologies present higher growth rates in both GDP and manufacturing value added, driven by faster productivity gains.[28] Specifically, the manufacturing sector is likely to benefit hugely from process, product, and organizational improvement, for example, through more effective and flexible automation and decentralization of tasks as well as better integration of hardware, software, and connectivity in production systems.

Industry 4.0 technologies could facilitate almost every aspect of business across sectors. For example, in the Philippines an agricultural robot system allows multiple hand tractors to perform agricultural tasks autonomously or guided by GPS sensor in a coordinated manner.[29] In Türkiye, automation, robotics, and AI systems are widely used (e.g., automotive manufacturers such as Tofaş and Ford Otosan) to increase the efficiency of production lines and improve quality control processes.[30] In Brazil AI systems to assist the analysis of X-rays

[27] https://www.unido.org/sites/default/files/files/2019-12/UNIDO%20IDR20%20main%20report.pdf
[28] https://www.unido.org/sites/default/files/files/2019-12/UNIDO%20IDR20%20main%20report.pdf
[29] Contributions from the Government of the Philippines.
[30] Contributions from the Government of Türkiye.

have been successfully adopted, making diagnosis more accurate and agile. Some hospitals also use chatbots for initial care and patient triage, relieving system overload.[31]

2. Fostering new industries

Technological advancements throughout history have given rise to new products and industries. From the advent of automobiles in the late 19th century to today's smart devices, technological breakthroughs have driven the growth and expansion of industrial production, thereby accelerating economic diversification.

A wide range of new products and industries has emerged due to the advancements of Industrial 4.0 technologies. For instance, the integration of AI and other Industrial 4.0 technologies has led to the creation of new products, such as personalized education tools, surveillance and inspection systems, or help advancing the deployment of upcoming ones as autonomous vehicles. Financial services are being revolutionized through digital payment systems, cryptocurrency, online banking, and blockchain technology, offering new services and business models including mobile payment, decentralized finance platforms, and asset tokenization.[32] Having said that, the exact form of innovation depends on the specific local conditions. Take mobile payment in Africa as an example, in view of the unstable and limited access of internet, it uses SMS to make transaction and has successfully provided financial services to millions of people who have mobile phones, but do not have bank accounts.

In a world of accelerated digitalization, Industrial 4.0 technologies have not only enhanced existing industries but have also created new markets centred around data-driven services and digital platforms, such as digital advertising and marketing platforms, fintech, telemedicine, and ecommerce, reshaping the industrial landscape and economic structure.

3. Promoting digital and green transition

Industrial 4.0 technologies could drive both technological upgrading and environmental improvements, thereby supporting digital and green transition. Apart from fostering the growth of service-oriented and knowledge-based industries, Industrial 4.0 technologies could also promote the development of new green industries such as renewable energy, electric vehicles, and products and services adapted to a circular economy; thus offering opportunities for developing countries to diversify their economies away from traditional resource-dependent industries.[33] The emergence of the green hydrogen value chain in developing countries is an example of green windows of opportunity for sustainable development.[34]

Diversification towards greener products is particularly important nowadays given the growing demand from consumers and governments for environmentally friendly goods and services.[35] While Industrial 4.0 technologies are not inherently eco-friendly, they can support green transition by revitalizing traditional industries. For example, AI can help optimize energy and water usage in the production processes of agriculture and manufacturing activities.[36] AI

[31] Contributions from the Government of Brazil.
[32] Contributions from the Governments of Cuba, Iran, Latvia, Peru, the Philippines, the Russian Federation and Türkiye.
[33] https://www.unido.org/sites/default/files/files/2019-12/UNIDO%20IDR20%20main%20report.pdf
[34] https://unctad.org/system/files/official-document/tir2023_en.pdf
[35] https://unctad.org/system/files/official-document/tir2023_en.pdf
[36] https://www.mckinsey.com/capabilities/operations/our-insights/how-manufacturings-lighthouses-are-capturing-the-full-value-of-ai

applications can also foster the introduction of new sustainable production models and processes,[37] but the higher propensity of large firms to invest or adopt AI might increases productivity gaps between firms. IoT can be employed to monitor environmental standards and detect illegal activities, as well as increase operational efficiency and enhance the design of more environmentally friendly modes of production.[38] The shift towards greener practices and modernization of traditional industries could promote the creation of new products, services, and business models targeting the needs of new generations and contributing to the diversification of economies in a sustainable manner.

C. Digitalization and challenges for economic diversification

Despite the potential benefits discussed above, Industry 4.0 technologies may curb traditional advantages of developing countries or limit the viable opportunities to diversify their economies. Three main interrelated channels are highlighted below: (i) reshoring, (ii) reducing demand for low-skill jobs, and (iii) widening of the productivity gap between developed and developing countries.

1. Reshoring

The productivity gains brought by Industrial 4.0 technologies make labour costs less relatively relevant than other factors like proximity to markets, supply chain resilience, and speed to market for companies' investment and location choices.[39] Moreover, the supply chain disruptions caused by the COVID-19 pandemic have prompted companies and governments to weight also resilience rather than only efficiency in supply chain management. This has induced firms in developed countries to bring production back to home or closer to their consumer markets.[40] This trend, known as reshoring, could lead to a reconfiguration of GVCs and reduce the offshoring of production in developing countries, thereby undermining their participation in GVCs and limiting their diversification opportunities.

Empirical evidence indicates a growing trend in reshoring, with Industrial 4.0 technologies being an enabling factor to reshoring.[41] Larger companies and those in high-tech industries show the highest likelihood of reshoring, yet it remains limited in scale.[42] Indeed, reshoring can be challenging as it takes time and significant investment to build the necessary infrastructure and train workers. Nonetheless, developed economies, such as the United States and the European Union, have actively launched policies to encourage reshoring, especially for critical sectors like semiconductors, electric vehicle, and green energy, with the aim of strengthening their industrial bases, safeguarding strategic sectors, and reducing reliance on other countries.[43] These increased incentives, along with the technological edge of developed countries, will make it more difficult for developing countries to engage in high-end stages of GVCs to upgrade and diversify their economies.

[37] https://www.tandfonline.com/doi/full/10.1080/13662716.2023.2213179#d1e1117
[38] https://unctad.org/system/files/official-document/tir2023_en.pdf
[39] https://onlinelibrary.wiley.com/doi/full/10.1111/1467-8551.12731
[40] https://sloanreview.mit.edu/article/a-reshoring-renaissance-is-underway/
[41] https://link.springer.com/chapter/10.1007/978-3-030-43589-9_3
[42] https://www.europarl.europa.eu/RegData/etudes/STUD/2021/653626/EXPO_STU(2021)653626_EN.pdf
[43] https://reshorenow.org/july-8-2024/; https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en; https://www.congress.gov/bill/117th-congress/house-bill/4346

2. Reducing demand for low-skill jobs

Industry 4.0 technologies can diminish the comparative advantage of cheap labour in developing countries by shifting the competitive focus to automation and skills, thereby altering the comparative advantages in global manufacturing and trade and limiting diversification opportunities.

Automated systems and robots can perform repetitive tasks more efficiently than human workers, reducing the need for manual labour in many production processes. The advancement of AI further broadens the set of tasks where the machine may have an advantage over humans and enables automation in those areas related to services or involving cognitive tasks.[44] For example, AI can monitor thousands of transactions at once for signs of fraud instead of having each one manually checked by human.

Apart from reducing demand for low-skill jobs, Industry 4.0 technologies are likely to increase labour demand towards technical and soft skills, such as systems management and critical thinking, that can manage and complement these advanced systems.[45] In other words, the competitive focus will be shifted from labour cost to the ability to implement and leverage advanced technologies. This poses challenges for developing countries that have traditionally benefited from a comparative advantage in global manufacturing due to their lower labour costs, making it difficult to maintain their roles in GVCs and diversifying their economies unless there is a substantial effort to reskill or upskill the workforce.

3. Widening of the productivity gap between developed and developing countries

History shows that the productivity gap between developed and developing countries has been widened after every wave of technological revolution.[46] While the exact impact of Industrial 4.0 technologies on the productivity gap depends on how these technologies are adopted and integrated into the economies, existing digital divide points to a relatively pessimistic picture.

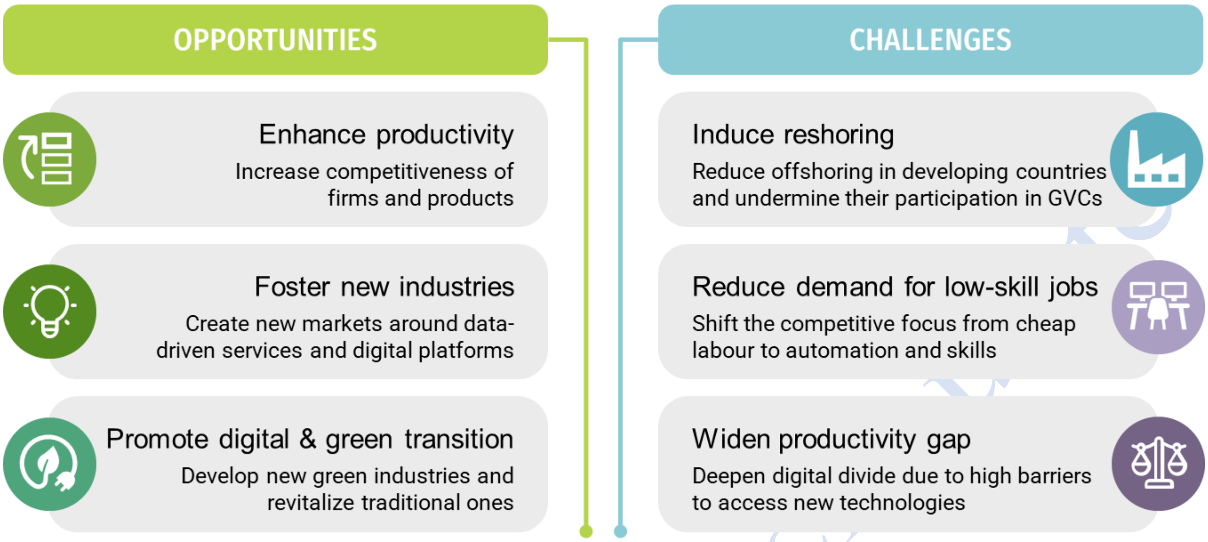
Currently, about one-third of the world population (or 2.6 billion people) does not have access to the internet, with most of them living in developing countries.[47] The lack of robust digital infrastructure hinders the effective adoption of Industrial 4.0 technologies in developing countries. Meanwhile, a significant divide persists in knowledge generation in these technologies, with developed countries dominating the associated publications and patents. This, coupled with the extremely high market concentration of technology providers in developed countries, creates high barriers for developing countries to complete or just access the technologies.[48] Moreover, as SMEs and workers in the informal sector of the developing world generally lack financial resources and specialized knowledge and skills, the capital-intensive and skill-intensive nature of Industrial 4.0 technologies makes it difficult for them to adopt these technologies.[49]

Unless developing countries put forward proactive policy measures to capitalize the benefits of increased digitalization and Industrial 4.0 technologies, they are likely to miss the

[44] https://www.aeaweb.org/articles?id=10.1257/jep.33.2.3
[45] https://www.cell.com/heliyon/fulltext/S2405-8440(23)05878-4; https://www.mdpi.com/2413-4155/4/3/34
[46] https://unctad.org/system/files/official-document/tir2023_en.pdf
[47] https://www.itu.int/itu-d/reports/statistics/2023/10/10/ff23-internet-use/
[48] https://unctad.org/system/files/official-document/tir2023_en.pdf
[49] https://www.sciencedirect.com/science/article/pii/S0040162518315737

opportunity to diversify and strengthen their economies and be left further behind as happened in the previous industrial revolutions. Figure 5 5 summarizes the opportunities and challenges for economic diversification in developing countries brought by Industry 4.0 technologies.

Figure 5: Opportunities and challenges for economic diversification



Source: UNCTAD elaboration.

III. Rethinking the role of industrial and innovation policies for economic diversification

Economic diversification, or the creation of new markets and industries, is grounded in the development, adoption, and adaptation of frontier technologies. This in turn highlights the importance of a technology-led diversification that should be incorporated into policy making to fit with today's economic and technological panorama largely shaped by advancement in digitalization. Of course, designing and implementing technology-led strategies can be a demanding exercise from a policy perspective, especially when moving closer to the technological frontier where uncertainty, risks (e.g., of failure or unintended consequences), and knowledge requirements are high. The efforts to drive a significant transformation and upgrade of the economy require a convergence between industrial and STI policies, particularly to foster technological diffusion, learning, and skill upgrading.

The rationales for policy action to boost innovation, industrial upgrading, and economic diversification are based on the concept of market failures, which tend to be more prevalent in less developed countries where non-market institutions are often less successful in addressing their consequences on the economy (Stiglitz, 1989). Rationales for industrial policies can be classified under three broad categories (Juhász et al., 2024). Frontier technologies add new rationales for policy intervention, that are intrinsically related to two sources of uncertainty, one related to R&D and innovation, the other related to the diffusion of new technologies in the economy and their impact (Box 1).

Box 1: Rationales for industrial policies

Externalities

Economic activity produces externalities when it creates effects in society that are not recouped in the revenues generated for those who carry out the activity. Learning and knowledge externalities, key for economic diversification, are related to innovation and new activities and the fact that the initial entrepreneur who makes the ''discovery'' (a new product, process, service or business model) can capture only a small part of the social value that this knowledge generates; if not supported, innovative activity can be fewer than the one required to experience a sustained and diffused structural transformation.

Coordination failures

The profitability for a producer may depend on the existence of related economic activities within the economy. This is a compelling issue for developing countries aiming at creating or supporting an industry that requires complementary assets. Coordination failures are related to a minimum scale of economic activities that can trigger further growth, and it is related to the complementarities needed for a successful digital transition. Coordination failures can arise from the interplay for the three key leverage points for the digital transition (infrastructure, data, skills). Their potential in supporting the adoption and development of frontier digital technologies can be limited by the under-provision of one the three, which make coordination crucial.

Activity-specific public inputs

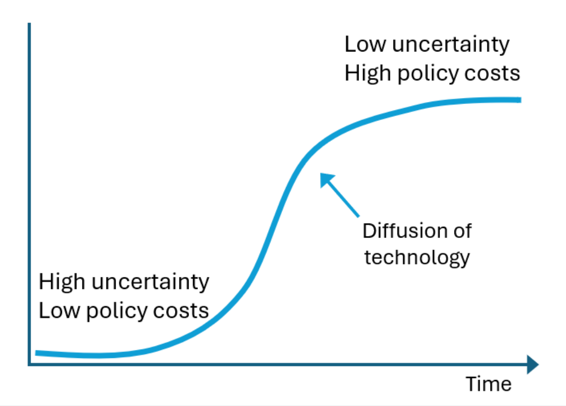
Private production depends on the provision of public goods, such as regulation, education or infrastructures. These public goods are often perceived as being provided through horizontal policies that do not prioritize certain activities or areas. However, because the needs of producers are largely specific to location, sector and the type of activity performed, horizontal interventions can benefit some parts of the economy more than others. For example, preferential taxation regimes linked to intellectual property to boost R&D investment of private firms will most likely benefit more those firms operating in high-tech and patent intensive sectors. Public goods can be provided also through more direct interventions such as an investment reinforcing digital infrastructure in rural areas, or a reform of the educational system to emphasize STEM and digital skill development.

Uncertainty and cumulativeness

R&D and the development of frontier technologies is characterized by a high degree of uncertainty about the results of a given endeavour, and by long-term horizons. At the inception of a new industry, many alternative approaches and models normally co-exist, with few surviving along the deployment of the industry. Science and technology typically follow a cumulative process and tend to become increasingly complex and require large investments to stay at or approach the frontier. Firms and industries at the frontier of technological development heavily invest in R&D and rely on basic research and external knowledge to keep pace with technological development, also relying on a critical mass of actors with STI skills outside the firm's boundaries. Moreover, the challenges associated with transforming scientific and technical knowledge into innovation and economic value in the business sector are relevant and can lead to failure (the so-called valley of death).

The dilemma of frontier technologies

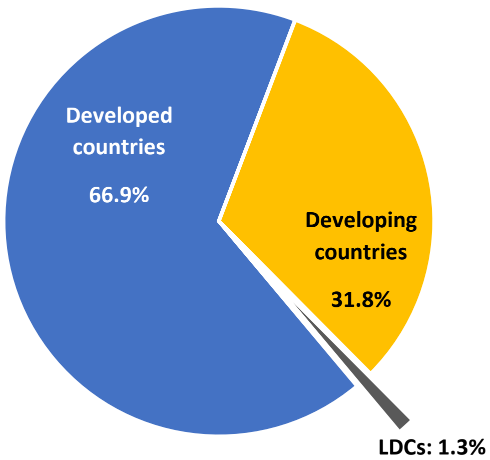
The governance of emerging technologies poses a well-known puzzle: during the early stages interventions and course corrections might still prove easy and cheap but the full consequences of new technologies, and hence the need for adjustments, might not be fully apparent. By the time consequences are apparent, control has become costly and slow (Collingridge, 1982). This is the cornerstone of the current discussion about anticipatory policies (OECD, 2024). At the point when countries must provide public goods, including basic research and infrastructures, to support the development and adoption of new frontier technologies, the government decision-making power is broad but mitigated by uncertainty about what the technology and the results of a given policy choice will be. As technology diffuses and the industry grows, uncertainty about the effective deployment is reduced but the difficulty and cost of government intervention to fix failures or impart direction increases.



A. The rise of industrial policies

Industrial policies have gained increasing importance in public discourse over the last years. According to Global Trade Alert (GTA) data,[50] since 2010 most of the policy interventions are from developed countries, while the role of least developed countries appears rather marginal (Figure 6). The GTA documents announcements of unilateral changes by governments that affect the relative treatment of foreign versus domestic commercial interests, i.e., trade in goods and services, investment as well as labour force migration. Because new interventions do not necessarily substitute for existing ones, the number of policies in force in each moment may increase over time (Evenett, 2019), making it more difficult for less endowed countries or firms to understand where opportunities and possible barriers are, possibly increasing burdens for SMEs and less developed countries.

Figure 6: Share of policy interventions, 2010-2021



Note: UNCTAD elaboration on Global Trade Allert (GTA) data, downloaded on 03 June 2024. The developing countries group does not include LDCs.

The renewed interest in industrial policies has been accompanied by a shift in the types of interventions that have been introduced in the last decade. Table 2 2 compares the 10 most frequently used types of interventions in 2010-11 with the ones for 2022-23. Overall, the rationale moved from import related measures – such as imports tariffs, anti-dumping and import tariffs quota – to a more direct intervention in the domestic productive sectors through financial grants, state loans and capital injections or production subsidies.

Table 2: Most frequently used types of intervention, comparing 2010/11 with 2022/23

[50] The GTA dataset provides data on actions and acts in the economic playing field of governments that can induce changes in international commercial flows (goods, services, investment, or labour force migration), introducing market distortions or altering the relative treatment of domestic commercial interests.

2010-2011			2022-2023	
Intervention type	%		Intervention type	%
Import tariff	22.4		Financial grant	13.6
Anti-dumping	10.9		Import tariff	12.9
Price stabilisation	10.7		State loan	9.3
State loan	9.7		Controls on transactions*	7.7
Trade finance	8.8		Export ban	5.9
Import tariff quota	7.8		Capital injection and equity stakes	3.6
Financial grant	6.9		Trade finance	3.6
Local content incentive	4.7		State aid, unspecified	3.5
Export tax	2.0		Import ban	3.5
Anti-subsidy	1.4		Production subsidy	3.0
Share of top 10 types of intervention	*85.2*		*Share of top 10 types of intervention*	*66.6*

Note: UNCTAD elaboration on GTA data downloaded on 03 June 2024. * Shorthand for "Controls on commercial transactions and investment instruments".

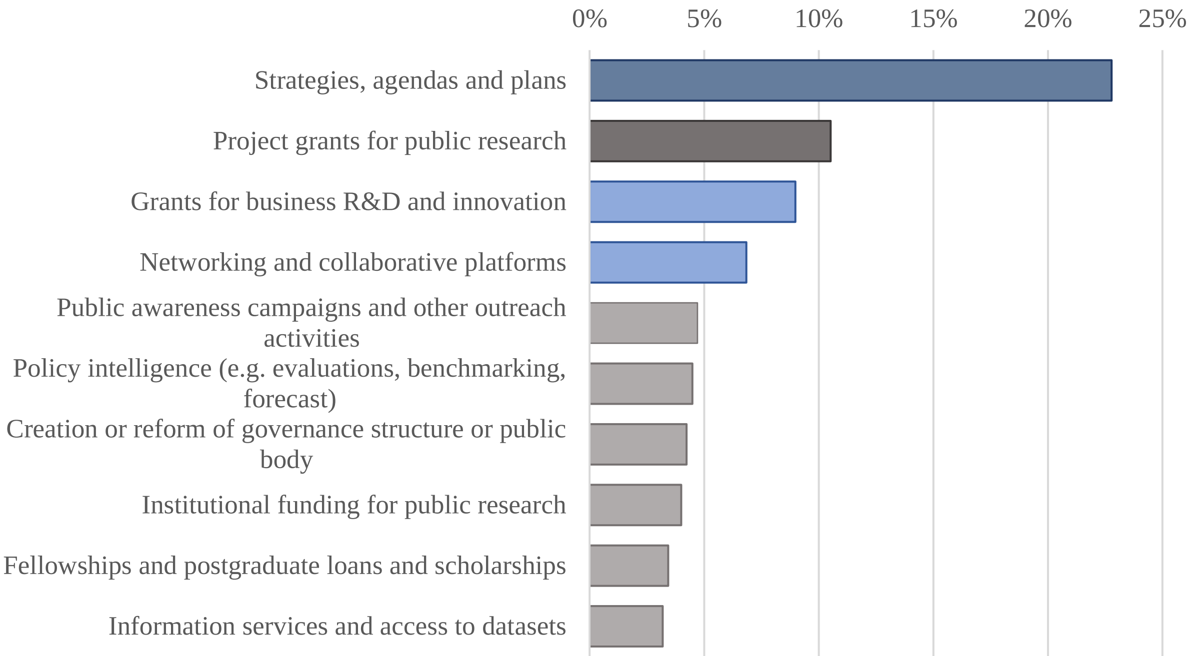
Moreover, a look at interventions across country groups during the 2022-2023 period reveals different approaches to policies interventions across country groups. Developed countries have relied more often than others on interventions aimed at controlling commercial transactions and investment instruments (12%) or limiting or prohibiting imports. Developing countries focus more on targeted financial subsidies to production or consumption (48%, about 10 percentage points more than developed countries) and tariff measures. LDCs are by far more focused on interventions supporting exports (more than 40%) or applying taxes on imports to match local ones, while the share of subsidies is much lower than that of the other country groups (19%).

B. STI policies in a world of accelerated digitalization

The growing importance of technology and digitalization in the policy agenda is reflected in the increasing number of STI policies over the years. Figure 7 ranks the most commonly used policy instruments in STI policies over the period of 2010 to 2022. About one out of five policy interventions are meant to set-up strategies, agendas, and plans. These include medium- to long-term guidelines to impart directionality to STI, define scopes, principles and objectives of policy action. This is also reflected in the contributions from CSTD members, which show that most countries have developed a STI strategy, digital agenda, or AI plan to set clear national priorities and roadmaps to guide the digital transformation process.[51] These are informed by a wide range of partnerships between different stakeholders, interactions between academia (or research institutes), industry, and government to tailor plans to the country innovation ecosystem, while the engagement of the civil society help directing technology and innovation toward societal needs.[52]

[51] Contributions from the Governments of Austria, Belize, Brazil, Cuba, Ecuador, Gambia, Germany, Indonesia, Latvia, Peru, the Philippines, Poland, Portugal, Russian Federation, Switzerland, Türkiye, United Kingdom, and Zambia.
[52] Contributions from the Governments of Austria, Belize, Brazil, Cuba, Ecuador, Gambia, Indonesia, Iran, Latvia, Peru, the Philippines, Poland, Portugal, Russian Federation, Switzerland, Türkiye, United Kingdom, and Zambia.

Figure 7: Most frequently used instruments in STI policies (2010-22)



Note: UNCTAD elaboration on STIP-OECD data (24 May 2024).

The other two most frequently used instruments are related to the support of research and innovation activities. Through a competitive process, project grants for public research are often provided to higher education or public research institutions to fund the costs of basic research projects, whereas grants for business R&D and innovation are usually offered to support applied research and development to address specific challenges or to favour the transition of science and new technologies to products in the market. The support of public and private research through competitive processes is a key factor to strengthen innovation potential of countries. While many countries have developed various funding programs, with strong support to SMEs and startups, some have further mobilized resources from the private sector and established public private partnerships to increase investment in research and innovation.[53]

The rise of digital technologies has made information and research results more easily and timely accessible, facilitating the diffusion of new ideas and potentially leading to a more participatory approach to science and innovation. While traditional industrial policies assume a relatively static process and adopt a top-down approach, an iterative process and a multistakeholder approach are essential to ensure an efficient feedback mechanism to accelerate the innovation process. This is reflected in the relative importance of instruments targeting networking and collaborative platforms or public awareness campaigns and other activities to reach civil society. These instruments aim at bringing together various actors within the innovation ecosystem to connect, exchange ideas, share resources, and collaborate. These platforms can also help to identify and address gaps in the innovation landscape, promote

[53] Contributions from the Governments of Austria, Brazil, Ecuador, Germany, Indonesia, Latvia, Peru, the Philippines, Poland, Portugal, Türkiye, and Zambia.

the sharing of best practices, and reduce the duplication of efforts for a better allocation of resources.[54]

Policies for innovation and frontier technologies deal with uncertain outcomes and long-term horizons, which make government learning a crucial aspect to improve policy design and be ready to address upcoming trends. Policy intelligence aims at gather, analyse, and disseminate information related to the design, implementation and impact of policies to support policy learning, inform decision-making and ensure that the STI governance system is aligned with broader societal goals. This requires assessing the extent to which a policy or program achieves its intended goals, examining possible unintended consequences of its implementation, and identifying key elements for success or failure to be able to efficiently redeploy specific actions in different contexts.

According to OECD data, the distribution of instruments differs between developing and developed countries and this is particularly evident when looking at AI, the digital frontier technology under the spot of most governments around the world. Financial instruments to support the development and diffusion of AI, such as grants for public research, business R&D and innovation, and student fellowships, are more frequently used in developed countries. Developed countries also use more frequently policies supporting AI computing and research infrastructures, all of which target the development and uptake of AI as well as the overall research capacities in the field. This somehow contrasts with what seen for traditional industrial policies where subsidies are more frequently used by developing countries and may be related to larger budgets dedicated to specific operational actions to support STI and frontier technologies of developed countries. In contrast, developing countries employ instruments that target the use of AI in the public sector more often. The incorporation of AI into e-government practices offers them a chance to expedite government processes, overcome limited resources or bureaucratic backlogs, and learn about AI through its use (United Nations, 2022), but this should not come at the cost of direct interventions to support STI in AI and create an supportive environment for business innovation in the field necessary to make declarative policies a reality.

In a world of accelerated digitalization, there is a growing need to reconsider the role of industrial policies in promoting economic diversification. Traditional industrial policies, which have focused on sector-specific support, must now expand to embrace a broader framework that encourages technological innovation, digital transformation, and the development of knowledge-based economies. Key to this rethinking is recognizing that economic diversification is no longer solely about expanding into new industries or reducing dependence on a single sector. Instead, it involves fostering inclusive and dynamic innovation ecosystems that leverage digital frontier technologies and adapt to global shifts in production and consumption patterns.

The distinctive features of digital frontier technologies shed light on the necessary changes. For example, the data-driven nature in digitalization warrant attention to data governance, including regulatory frameworks and standards on data sharing and privacy protection. While traditional industrial policies often focus on product standards, the decision-making autonomy of digital frontier technologies like AI requires new frameworks that regulate not just products

[54] Contributions from the Governments of Austria, Brazil, Gambia, Germany, Indonesia, Peru, the Philippines, Portugal, Russian Federation, Türkiye, and United Kingdom.

but the decision-making processes to ensure transparency, explainability, ethics, and accountability. New approaches to intellectual property law are also needed in view of the intangible nature of digital technologies in contrast to the traditional focus on physical goods.

In short, supporting structural change and productivity growth can no longer be a policy goal without considering the direction of technological advancement. A well-coordinated STI strategy that involves different stakeholders and considers other policy domains is needed to steer technological change in a direction that aligns with the national development agenda.[55]

[55] https://drodrik.scholar.harvard.edu/files/dani-rodrik/files/rebirth_of_industrial_policy_and_an_agenda_for_the_21st_century.pdf

IV. Preparing to benefit from technology-led diversification and upgrading

While the previous sections illustrate how frontier technologies can facilitate economic diversification, this section focuses on the supporting systems to take advantage of these opportunities. Three crucial components shape the adoption and development of digital frontier technologies: infrastructure, data, and skills. The effective provision and availability of these components are supported by cross-cutting resources such as funding, public support, and multistakeholder collaboration, emphasizing the need for an integrated approach when preparing countries for technology-led diversification and upgrading.

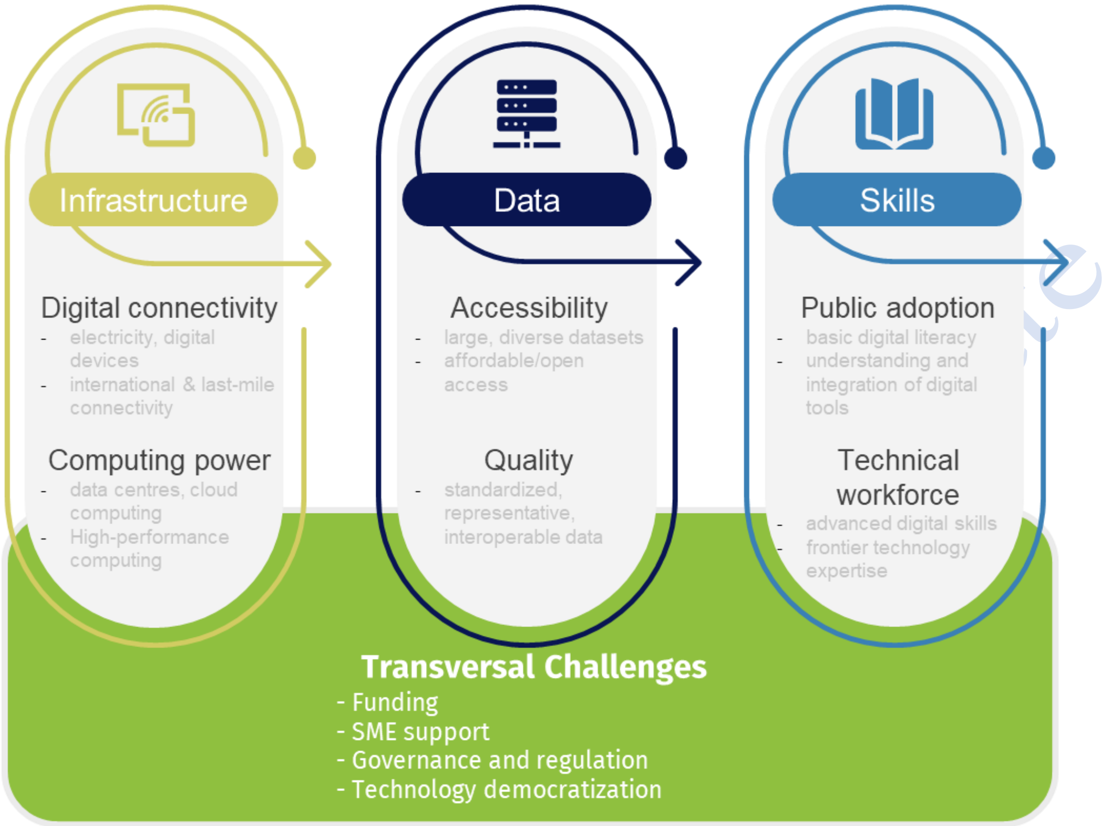
The three crucial components of digital frontier technologies rely on physical elements, such as semiconductors and ICT components forming the basis of data processing and frontier technology computing to digital infrastructure and networks connecting computing systems and data centres. Skills are also crucial to develop and adopt digital enabled solutions. For example, highly skilled developers are needed to develop foundation AI models, and to train and apply algorithms to different data and projects. These foundation models are then distributed and adopted across sectors, requiring increasingly dense and efficient infrastructure; larger, more precise, and localized datasets; and a variety of broad technical and digital skills for an effective use in the local context.

The critical components of digital transformation are not equally present in all countries, with many places struggling with outdated infrastructure and limited technological accessibility that curtail the equitable adoption of frontier technologies. This digital divide reinforces structural inequities both within and between countries; developed regions have more resources and infrastructure to promptly use and apply frontier technologies while developing areas continue to struggle with the basic elements required to access them.[56] In other words, the digital transformation can potentially broaden rather than close existing divides, because gaps in digital infrastructure and inclusion will be replicated in the AI uptake (Bentley et al., 2024). Proactive policy measures are needed to ensure that developing countries can address these challenges by developing the necessary elements, resources, and ability to take advantage of frontier technologies.

Based on the literature and the contributions from member States and international organizations, the key challenges faced by developing countries in seizing the benefits of technology-led diversification are structured into three crucial components - infrastructure, data, and skills - with the consideration of other cross-cutting factors (Figure 8).

[56] Contributions from the Government of Cuba and ITU.

Figure 8: Key challenges of harnessing the benefits of technology-led diversification



Source: UNCTAD elaboration on country inputs.

A. Infrastructure

A crucial challenge in adopting and developing frontier technologies is establishing robust digital infrastructure, including digital connectivity and computing power. Both digital connectivity and computing power rely on the efficient and sustainable use of natural resources, including reliable and affordable energy as well as minerals for the manufacturing of hardware components and water to cool processing centres. The local availability of these resources in the country or region of use can shape national approaches to developing frontier technology infrastructure, incorporating how they are accessed, imported or transported.

Digital connectivity provides essential links between actors and systems to distribute information and computing power throughout and between countries. It includes both internet and electricity as basic infrastructure that have been central to development plans in the last few decades. Many of these networks are still underdeveloped, aging and outdated, meaning that many countries still struggle with ensuring quality and stability of digital connectivity.[57] In addition, about one-third of the global population, or 2.6 billion people, is still offline (International Telecommunications Union, 2023), and much of this population is in rural areas, suffering from the lack of last-mile distribution.[58] However, this is also affected by a persistent usage gap: many people still do not use the internet despite the increasing availability of

[57] Contributions from the Governments of Belize, Cuba, Iran, Peru, the Philippines and Zambia, as well as ESCAP, ESCWA, ITU, OSET and UNTBLDC.
[58] Contributions from the Governments of Latvia, Peru, the Philippines and Portugal.

infrastructure and connectivity (International Telecommunications Union, 2024). This suggests that rather than exclusively focusing on broadband penetration, developing countries should also address other challenges, including access and affordability to digital devices and services (Roberts and Hernandez, 2019; International Telecommunications Union, 2024).

While digital connectivity enables the adoption and diffusion of new technologies, these are often purchased or brought from outside sources. The development of a domestic technology industry can lead economic diversification by facilitating technological upgrading in other industries. The development of frontier technologies requires intense computing power, which at the end uses semiconductors, as well as high-performance storage and security, backup systems, data centres, and cloud computing. AI and big data increasingly require computing power to train and apply modern machine learning, making it a critical part of high-tech industries. However, developing countries face many significant challenges in acquiring computing power, including accessing specialized hardware, developing high-performance and high-speed computing networks, or interfacing with cloud and international computing.

Because computing power builds on existing ICT networks, it also suffers from the barriers to digital connectivity mentioned above. In particular, computing power is often less diffuse than ICT networks due to the concentration of data centres and supercomputers in strong industrial or research areas. Improved digital connectivity can help distribute computing power, allowing for increased adoption and development of digital frontier technologies for economic diversification. However, many countries lack the computing resources that can handle the high intensity needs of AI and frontier technologies.[59] High-performance semiconductor chips that are crucial to frontier technology are almost entirely produced by the United States and other developed countries (Semiconductor Industry Association, 2024). Many developing countries either depend on other countries for shared computing power or would need to invest significant resources in developing high-level computing infrastructure from scratch.

B. Data

Data form the central component of all frontier technologies, serving as both the primary input and output for training algorithms and models. The ongoing "data revolution" has transformed society's relationship with data, shifting from existing as mere information to guiding policy and decision-making (The United Nations Secretary-General's Independent Expert Advisory Group on a Data Revolution for Sustainable Development (IEAG), 2014). New and emerging data sources mean that the amount of data collected has skyrocketed globally, and the ubiquity of mobile (smart) phones has contributed to the growing production of citizen-generated data (MacFeely, 2020). Despite this, many developing countries still face significant challenges in acquiring data, ensuring their quality and security, and processing them for use in frontier technologies (OECD, 2017).

Machine learning and deep learning models require increasingly large datasets that are too complex for traditional statistical models. However, these requirements are stretching the limits of what is currently available in developing countries,[60] which have historically suffered from data poverty: limited volume, variety, and velocity (Chandy et al., 2017). In additional to data

[59] Contributions from the Governments of Austria, Brazil, the Gambia, Iran, the Russian Federation and the United Kingdom, as well as OSET.
[60] Contributions from the Governments of Brazil, the Gambia and Zambia, as well as ITU and UNTBLDC.

availability, many developing countries do not have enough capacity for data storage and processing, intersecting with the infrastructure issues. These large data sets are used for developing foundation models, making the limited existence and availability of data a significant challenge for the creation of AI solutions and other frontier technologies applications.

These limitations in data access extend to the diffusion of frontier technology, as adoption requires algorithms that can be tailored to specific sectoral needs. To prevent issues of bias and ensure that models are applicable to their use case, this process requires data from the intended target use, either from an industrial sector or a community. Many developing countries find accessing sectoral data a challenge,[61] although the increase in both private data markets and open data approaches offer new avenues for providers and developers to share and acquire the necessary data.[62]

In order to be effectively utilized, these datasets need to be large, of good quality, representative, interoperable, accessible and secure. The difficulty of achieving these qualities varies by country. Places with smaller populations have a lower capability to generate local data sets to work with; moreover, limited digital connectivity might render datasets incomplete or seldom updated, data might not be available in the local language, or outdated technical systems could make it difficult to access and utilize data.[63] There are also challenges in collecting quality data, including ensuring survey comprehension, reducing response bias, training skilled research staff, and addressing systemic issues and institutional pressures (Chandy et al., 2017; OECD, 2017). These issues permeate the STI ecosystem, calling into question the usability of existing datasets as well as the collection process for new data.

Moreover, as more datasets and types of data are collected, cleaned, distributed and processed, new questions arise about information security and privacy, surveillance, or data ownership (Lee et al., 2024). In response to public concerns about the safe collection, usage and integration of data, data governance issues have been growing in scale. Ensuring that data is available, secure, and protected is an urgent priority for developing countries,[64] many of which do not have data protection and privacy legislation in place or may face challenges when dealing with large multinationals companies in their implementation. This challenge is compounded by the interconnected nature of cross-border data flows, which means that national policies can have spill-over effects on other countries; regardless of their domestic policy ecosystem, developing countries face challenges regarding uncertainty and compliance costs in adhering to national and international data governance standards (UNCTAD, 2024a). Existing or draft data governance policies also need to be evaluated and adapted to apply to AI and other frontier technologies, with a dedicated balance between addressing specific concerns and ensuring that regulations do not limit the availability of data for development.

C. Skills

Technology-led economic diversification requires the availability of a skilled workforce with technical expertise like data science or specialized AI knowledge, alongside communication,

[61] Contributions from the Governments of Belize and the Russian Federation, as well as UNTBLDC.
[62] Contributions from the Government of Indonesia.
[63] Contributions from the Governments of Belize, Peru and Zambia, as well as ITU and UNTBLDC
[64] Contributions from the Government of the Philippines and UNTBLDC.

management, and other complementary and transversal skills. The labour force in high-tech industries spans from highly skilled engineers creating computer chips and developers coding algorithms to workers and users with the digital skills and industry knowledge to understand and apply AI in their field. In addition, widespread AI adoption depends upon population-wide digital literacy in order for citizens to engage with these tools in all sectors. However, developing such a workforce poses a significant challenge to many developing countries that still struggle with relatively low levels of digital literacy and foundational digital skills (Fietz and Lay, 2023).

Economic diversification in the age of digitalization relies on digital literacy and a good understanding of frontier technologies to support their diffusion and application throughout diverse markets and economic activities. Ironically, data on digital literacy is scant (International Telecommunications Union, 2023), but many developing countries report a significant shortage of population-wide digital skills.[65] While global digital literacy is on the rise, it still remains unevenly distributed between developing and developed countries: the global median percentage of the population with data literacy is hovering at only 56 per cent (International Telecommunications Union, 2023). Beyond basic digital skills, the ability to use and understand digital frontier technologies in context is crucial to facilitate wider uptake, including skills such as prompt engineering, data analysis, and domain expertise. Many developing countries struggle to develop and support these skills across the population, which hinders the use and diffusion of frontier technologies across sectors.[66]

Many countries, included developed ones, are also in need of highly skilled workers that have AI and frontier technology-specific skills.[67] Most commonly, these skills are developed through tertiary education programs, but can also come from industry training and partnership programs. Comprehensive education and training programs can target STEM skills needed for digital frontier technologies at all ages and levels of society, through re-skilling, up-skilling, and cross-skilling (UN and ILO, 2024).

These education and training programs also need to address specific labour concerns raised by the frontier technologies, related to inclusion, accessibility, and job insecurity. The global rise in automation is a particular concern for developing countries, as it is dismantling their long-held advantage in low-cost labour for manufacturing . Reskilling programs can support workers from jobs at risk of automation to develop new capacities and move to new jobs opportunities created by frontier technologies.[68] These programs should also target vulnerable groups such as women, youth, older persons, and indigenous communities, all of which face unique barriers to participate in the digital economy.[69]

Beyond training and skills development, developing countries also face significant concerns about retaining human capital.[70] Without domestic job opportunities, the development of a highly-skilled workforce can lead to human capital flight, or "brain drain," where talented

[65] Contributions from the Governments of the Gambia and the Philippines.
[66] Contributions from the Governments of Brazil, Indonesia, the Philippines and Poland, as well as ITU and OSET.
[67] Contributions from the Governments of Belize, Brazil, Iran, Latvia, Peru, Philippines, the Russian Federation, Türkiye, the United Kingdom and Zambia, as well as ESCAP, ESCWA, ITU, OSET and UNTBLDC.
[68] Contributions from the Governments of the Philippines and Poland.
[69] Contributions from the Government of Austria.
[70] Contributions from the Governments of Austria, Brazil, Iran and Peru.

individuals emigrate to places with more-developed job markets (Roudgar and Richards, 2015). While some governments rely on these expatriates as a source of remittance income (Rodrik, 2004), the lack of participation in domestic industries is of particular concern for low-income and developing countries as the highly-skilled workforce is already quite small (Altenburg, 2011).

Technologies have enabled workers to participate in the global job market easily. While the top countries offering software development and IT services are almost all developing countries, most of these services are being offered to firms located in the United States and Europe (Stephany et al., 2021). This presents both potential opportunities and challenges to developing countries: on the one hand, these remote workers can bring jobs and income to foster more resilient local communities, participate in the international knowledge society, and take advantage of such an international diaspora through the creation of professional and knowledge transfer networks (Meyer and Brown-Luthango, 1999). STI fields like AI most benefit from these knowledge transfer and sharing policies because they facilitate access to foreign-produced knowledge for domestic innovators (Agrawal et al., 2011; Meyer and Brown-Luthango, 1999). On the other hand, the skills of these workers are benefiting the development of technology outside their home countries and failing to contribute to a domestic STI ecosystem (UN and ILO, 2024). The freelance market is not limited to highly skilled workers, but also widely present in low-skilled data labelling and content moderation works primarily done in developing countries (UN and ILO, 2024).

D. Cross-cutting factors

Apart from these three crucial components, there are other cross-cutting factors that shape the wider STI ecosystem, including funding, private sector uptake, public support, governance and regulation, and the democratization of technology. While infrastructure, data, and skills fulfil the concrete needs of the digital transformation, a successful technology-led diversification will rely on holistic support from the wider social and economic system.

Of primary concern to many developing countries is funding research and development;[71] regions the most in need of investment are often places with limited available funds for upgrading digital infrastructure, establishing data centres, and training, upskilling and retaining workers. Government support can be supplemented by private investment by creating a favourable investment market,[72] supporting a strong startup and entrepreneurship culture,[73] and reducing high interest rates and tax burdens for the industrial sector.[74]

Another important factor is the engagement of the private sector in using and disseminating frontier technologies. Small and medium enterprises (SMEs) in particular need support in order to be able to adopt AI and other frontier technologies. They struggle with accessing funding to purchase these technologies, out-of-date equipment that is unable to support complex AI systems, limited managerial capabilities to adapt business processes and navigate the digital

[71] Contributions from the Governments of Ecuador, Latvia, Peru, Türkiye and Zambia, as well as ITU and UNTBLDC.
[72] Contributions from the Governments of Brazil, Iran and the Russian Federation, as well as UNTBLDC.
[73] Contributions from the Governments of Peru and Türkiye.
[74] Contributions from the Government of Brazil.

transition.[75] These factors interact with infrastructure, data, and skills as well, as high costs, lack of digital skills and weak digital infrastructure also hinder the productive use of frontier technologies by SMEs in developing countries.

Public support and excitement for frontier technologies can drive investment and engagement, but there is a global lack of awareness and understanding of the role of AI and other digital frontier technologies in daily life and their potential for economic transformation.[76] In addition, even those who are aware of AI may fear or distrust it because of the perceived lack of oversight and human intervention in decision making.[77]

Governments can direct the public response to frontier technologies by developing policies and regulations that ensure trustworthy and human-oriented digital products. Digital frontier technologies introduce new challenges and exacerbate existing digital debates on issues like cybersecurity, network neutrality, data privacy and ownership, user rights, intellectual property, ethical use, energy efficiency and climate impacts and fair competition.[78] Responsive regulations can be both supportive and protective, encouraging industrial growth and development while protecting citizens and human rights.[79] However, the development and adoption of these policies can be hindered by limited government capabilities, lack of resources, and political instability.[80]

Lastly, the democratization of technology is an important consideration for the digital transformation. A few large technology companies currently control the development and distribution of AI and other frontier technologies,[81] which add to the concentration of resources and assets in developed countries.[82] Because of this, many developing countries lack domestic AI resources and programs that are in local languages and incorporate cultural specificity.[83] Multistakeholder collaboration in knowledge exchange and technology transfer plays an important role in disseminating technology, developing R&D infrastructure, and building up the capacities of participating countries to address their own technology-led diversification needs.

[75] Contributions from the Governments of Belize, Brazil, Ecuador, Indonesia, Latvia, Peru, Portugal and Türkiye, as well as ESCAP, ESCWA and UNTBLDC.
[76] Contributions from the Governments of the Gambia, the Philippines, Portugal and Zambia.
[77] Contributions from the Governments of OSET.
[78] Contributions from the Governments of Brazil, Cuba, Indonesia, Peru, the Philippines, the Russian Federation and Switzerland, as well as ESCAP, ESWA, ITU, OSET, UNTBLDC and WIPO.
[79] Contributions from the Governments of Iran and Peru, as well as ESCWA, ITU, OSET and UNTBLDC
[80] Contributions from the Governments of Indonesia and Peru.
[81] Contributions from the Governments of Brazil and Portugal.
[82] Contributions from the Government of Brazil.
[83] Contributions from the Government of Latvia and OSET.

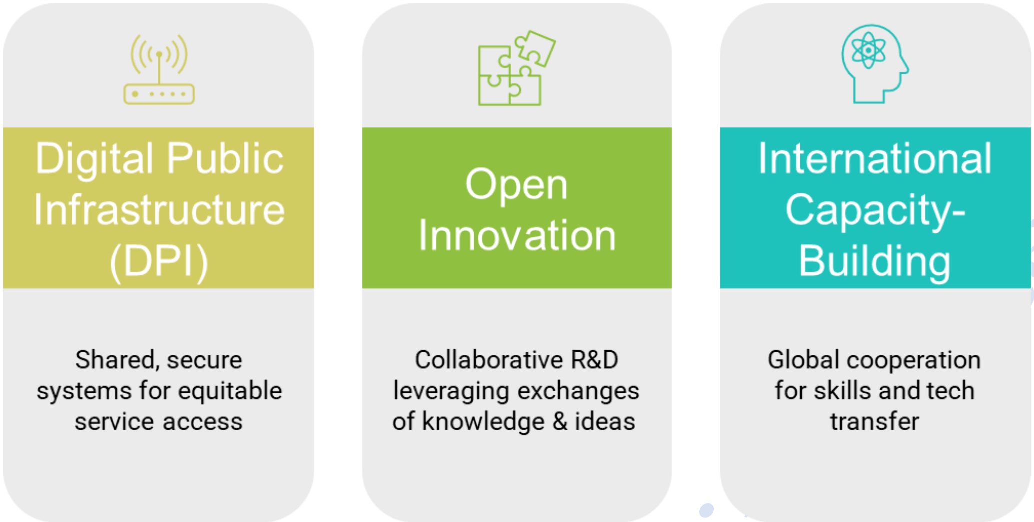
V. Leveraging frontier technologies for inclusive economic diversification

To support economic diversification, countries face challenges affecting the inclusive development and adoption of frontier technologies. While some of these challenges are specific to local conditions, many transcend national borders and should be considered by the international community. For example, modern digital infrastructure such as cloud computing provides global connectivity without any reliance on geography. Digital infrastructure supports the growing global data flow, which has seen a four-fold increase from 2018 to 2023 (UNCTAD, 2024b). These cross-border data transfer operations include digital trade, international commerce, internet platforms and services, and data collection and analysis (Nakanishi and Hori, 2023). Skill and knowledge transfers are another cross-border element of the digital transformation, with workers participating in the global labour market either through virtual work or by moving to other countries with more or better job opportunities.

Indeed, digital global value chains stretch across continents, virtually and physically connecting mineral extraction, manufacturing, data processing, and application diffusion (UNCTAD, 2024b). Few large multinational technology firms act as the primary global developers and distributors of digital frontier technologies and new technology systems deployed in multiple countries at once which means that guaranteeing fair competition and access to technology is not only a national issue and necessitate coordinated international efforts and responses. Moreover, increased complexity of products and services, coupled with more stringent intellectual property (IP) regimes, contribute to slower technology diffusion. For example, regulatory changes aligned with the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) tend to increase patent activities, but in many developing countries this process is led by foreign companies rather than domestic ones. This calls for a reflection on the extent to which more stringent IP regimes favour the globalization strategies of large high-tech corporations at the expense of new entrants or the development of high-tech industries in countries not at the technological frontier (Arza et al., 2023).

During the years, the CSTD has contributed to facilitating global cooperation in science and technology by acting as a forum to discuss issues raised by rapid technological change, advance the understanding of science and technology policies, share good practices and lessons learned, and support the strategic planning in STI, particularly for developing countries. The following sub-sections outline three propositions for effective global collaboration to leverage digital frontier technologies for inclusive economic diversification (Figure 9) and address practical challenges at international scale regarding digital infrastructure, data, and skills. The section closes by discussing emerging data and AI governance frameworks at the international level.

Figure 9: Three propositions for effective global collaboration



Source: UNCTAD elaboration.

A. Digital public infrastructure

Digital Public Infrastructure (DPI) is a set of shared, secure and interoperable digital systems that can be built on open standards and specifications to deliver and provide equitable access to public and private services at societal scale.[84] Compared with the traditional public infrastructure such as roads and bridges, DPI is often referenced as the infrastructure of the digital era, comprising digital systems and applications that can be used flexibly and adapted to different use cases and sectors. The DPI approach can represent an effective way to address infrastructure challenges in developing countries, enabling them to develop tailored DPI systems, such as electronic registries, digital payment, and digital commerce, to drive technology-led structural transformation and industrial upgrading.

DPI has emerged as a driver of inclusive digital transformation and a catalyst to accelerate the SDGs. Indeed, there are many successful DPI experiences across countries. For example, a DPI approach led the way for digital identity provision to more than a billion people in India, allowing also for payments and biometric security; a DPI platform in Togo disbursed social assistance to about 450,000 people within a week during the pandemic; and a DPI platform in Estonia facilitated the secure exchange of data across consumers, energy distributors, and producers to enhance decision making in the energy sector.[85] It is estimated that the implementation of DPI in the financial sector can boost economic growth of low- and middle-income countries in the coming years by. Meanwhile, DPI in the climate economy is expected to bring benefits to carbon offsets and trading, accelerating the reduction of carbon dioxide emissions and allowing to reach reduction targets 5 to 10 years in advance.[86]

DPI has gained the front stage in global discussion in recent years. As outlined in the G20 New Delhi Leaders' Declaration, countries reached a consensus on the definition of DPI in 2023 and

[84] https://g7g20-documents.org/database/document/2023-g20-india-sherpa-track-digital-economy-ministers-ministers-language-g20-digital-economy-ministers-meeting-outcome-document-and-chair-summary
[85] https://www.undp.org/publications/accelerating-sdgs-through-digital-public-infrastructure-compendium-potential-digital-public-infrastructure
[86] https://www.undp.org/publications/human-and-economic-impact-digital-public-infrastructure

acknowledged DPI as a promising approach to digital transformation by providing a shared technology infrastructure that can be built and leveraged by both the public and private sectors.[87] There have been increased commitment and efforts from the international community to leverage DPI for sustainable development, for example, through the GDC,[88] the G20's Digital Economy Working Group, various programmes and initiatives of UNDP[89] and the World Bank,[90] and the declaration of the Shanghai Cooperation Organization[91]. Building on these efforts, DPI could be scaled up to support countries in upgrading their economies, and to build inclusive and innovative ecosystems. Empowering societies and individuals to direct digital technologies toward their development needs would contribute to increasing economic and social opportunities for all.

B. Open innovation

To address the challenges developing countries encounter in terms of data and skills, open innovation introduces a novel approach to manage the innovation process and enable knowledge-sharing among independent innovators, companies, institutions, and countries.[92] Instead of relying solely on internal capabilities, the open innovation model encourages tapping into the vast pool of external ideas to speed up research and development, lower costs, and enhance the quality or relevance of innovation outcomes.[93]

In today's rapidly evolving digital world, open innovation plays a key role in economic diversification by fostering collaborative ecosystems where individuals, firms, and countries can harness the latest technologies, share data, and external knowledge to accelerate time to market, engage customers directly in the innovation process, and exchange ideas to unlock new opportunities. One of the recent milestones is the Manaus package released by the G20 Research and Innovation Working Group under the Brazilian presidency, which includes an open innovation strategy to foster international collaboration on STI. The strategy puts forward principles, approaches, and tools that can pave the way for inclusive and equitable international initiatives in STI.[94]

While concepts and approaches to open innovation are still evolving, there are some useful instruments that can contribute to the setup of a global open innovation strategy for frontier technologies.[95] For instance, open data aim at making data freely available to anyone to access,

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87 https://g7g20-documents.org/database/document/2023-g20-india-sherpa-track-digital-economy-ministers-ministers-language-g20-digital-economy-ministers-meeting-outcome-document-and-chair-summary

88 https://www.un.org/techenvoy/sites/www.un.org.techenvoy/files/general/GDC_Rev_3_silence_procedure.pdf

89 https://www.undp.org/digital/digital-public-infrastructure

90 https://www.worldbank.org/en/results/2023/10/12/creating-digital-public-infrastructure-for-empowerment-inclusion-and-resilience

91 https://eng.sectsco.org/20240709/1438929.html

92 https://www.emerald.com/insight/content/doi/10.1108/14601060410565074/full/html

93 For example, the European Commission characterizes the concept of open innovation as combining the power of ideas and knowledge from different actors to co-create new products and find solutions to societal needs as well as creating shared economic and social value, including a citizen and user-centric approach. https://op.europa.eu/en/publication-detail/-/publication/3213b335-1cbc-11e6-ba9a-01aa75ed71a1

94 https://www.g20.org/en/

95 Under the Brazilian presidency of the G20, the Research and Innovation Working Group has recommend the creation of a G20 Open Innovation Strategy to promote international open innovation initiatives that benefit all involved stakeholders.

use, modify, and share, and play a crucial role in the development of AI and other frontier technologies.[96] Open data can foster innovation by allowing researchers and developers to experiment with data and create new solutions as well as to improve transparency and fairness in the development of new applications. The Human Genome Project,[97] COVID-19 Open Research Dataset,[98] and the Human Connectome Project[99] represent some of the key examples of successful open data projects.

Open source is another important instrument that has diffused widely in software development. It is a software development model where the source code, design, or blueprint of a software or project is made freely available to the public. By providing free and open tools, libraries, and frameworks, open source can democratize knowledge and resources, enable global collaboration and innovation, and improve transparency and trust. Well known applications based on open source include Linux and Android, and currently we are experiencing to an explosion of open-source AI and GenAI projects which ranges from commercially backed large language models to applications developed by academic institutions and individual developers.[100]

Beyond software development, many innovators are already creating open-source designs and technologies, but the lack of a central repository limits access for producers in developing countries. To address this, the Economic and Social Council of the United Nations adopted the resolution 2021/30 which calls for a centralized repository of open-source technical information including data, plans, but also digital design and manufacturing files, and instructions for assembly and use to overcome barriers to the building and dissemination of the global stock of knowledge.[101] Establishing and operationalizing such a database would require donor funding.

C. International cooperation on capacity-building

Along with the open innovation approach, there is a need for the international community to take proactive actions to promote the transfer of knowledge and technology to developing countries and augment their capacity of absorption, thereby empowering them to actively engage in the adoption and development of frontier technologies. On the one hand, international dialogues, global networks of exchange, and technical cooperation initiatives are essential for sharing good practices and disseminating knowledge to enhance the competitiveness of national industries and harness frontier technologies for economic diversification. On the other hand, technical assistance and tailored solutions should be implemented based on local needs and absorption capacities of less technologically advanced developing countries to ensure an effective transfer of technological knowledge.[102]

While knowledge and technology transfer generally focus on specific information or skill, capacity building encompasses a broader range of capabilities that will empower individuals

[96] Contributions from the Government of Austria.
[97] https://www.genome.gov/human-genome-project
[98] https://github.com/allenai/cord19
[99] https://www.humanconnectome.org/
[100] https://github.blog/news-insights/research/the-state-of-open-source-and-ai/
[101] https://documents.un.org/access.nsf/get?OpenAgent&DS=E/RES/2021/30&Lang=E
[102] Contributions from the Governments of Brazil, Cuba, Indonesia, Latvia, Peru, Poland, Portugal, Switzerland, Türkiye and Zambia, as well as ESCWA, OSET and UNTBLDC.

or countries to continue growing and developing independently. Capacity building is particularly important for the adoption and development of rapidly evolving frontier technologies. These activities, ranging from training workshops that help increase capacity to develop STI policies to tailored educational programmes and R&D partnerships that advance research and technological skills, could equip stakeholders in developing countries with the necessary capabilities to use, adapt, and develop frontier technologies.[103]

Digital frontier technologies have a significant impact on the workforce, mainly through automation that replaces workers and argumentation that supports labour, and it is essential to provide reskilling and upskilling programmes to help the workforce transit to new occupations and tasks.[104] For jobs that are likely to be replaced by automation, the focus should be on reskilling workers to acquire new skillsets and move to other jobs; for those who may benefit from AI and other frontier technologies, upskilling could help them making a good use of the latest technologies and tools to achieve productivity gains, whereas cross-skilling could expand their capabilities, enabling them to enhance their roles.[105]

To build a skilled workforce and prepare for possible transformations ahead, the international community could support developing countries to establish robust educational and lifelong training frameworks that apply the most updated educational approaches, incorporating digital skills into existing educational curriculums and providing tailored training programs based on the level of exposure to automation and argumentation of different occupations.

Equally important is the improvement of labour market opportunities to offer attractive career development opportunities and support continuous upskilling, thereby preventing the de-skilling of workers or brain drain. Partnerships between, on the one hand, the private sector as the major originator of frontier technologies and jobs, and on the other hand, the government and academia, offer significant potential to develop capacity-building initiatives for quality employment, such as placement programmes, apprenticeship and industry-academic research collaborations. Yet, small developing economies can be less attractive for or have relatively low bargaining power with large high-tech companies, which can limit the policy space of socially beneficial public-private partnerships. The international community can facilitate and support such strategic partnerships for quality jobs, knowledge transfer, and opening avenues to diversify into emerging industries.

D. Emerging discussion on data and AI governance

There is a wide variety of initiatives by the UN and other international organizations that present solutions to accelerate the development and uptake of inclusive frontier technologies; however, they are rather fragmented and would benefit from reinforced coordination. The ongoing discussion of data governance and AI frameworks are two illustrative examples.

Data governance has become an important issue over the last decades, as digital technologies began to interact with and require increasingly more and diverse data sets. Most existing data protection legislations are based on the OECD Privacy Guidelines, which was the first attempt to create global common standards for data protection back in 1980 (Bernier et al., 2022).

[103] Contributions from the Governments of Belize, Brazil, Cuba, the Gambia, Indonesia, Poland, Portugal and Zambia, as well as OSET and UNTBLDC.
[104] https://academic.oup.com/economicpolicy/article-abstract/34/100/589/5709812
[105] https://www.ilo.org/publications/major-publications/mind-ai-divide-shaping-global-perspective-future-work

In 2016, the European Union adopted the General Data Protection Regulation (GDPR), which established regulations for how personal data is processed in the EU and formalized data-specific rights such as data erasure and data portability, presenting a new global standard for "data protection by design and by default" (European Parliament and Council of the European Union, 2016). This rule had huge spillover effects, as it also necessitated the application of its rules outside the EU in order to protect individuals in the EU, rendering normative interoperability subordinate to the protection of human rights. Moreover, the GDPR has encouraged other jurisdictions to develop common and interoperable standards to facilitate data transfer between international destinations and inspired many legislations protecting citizens' rights around the world.

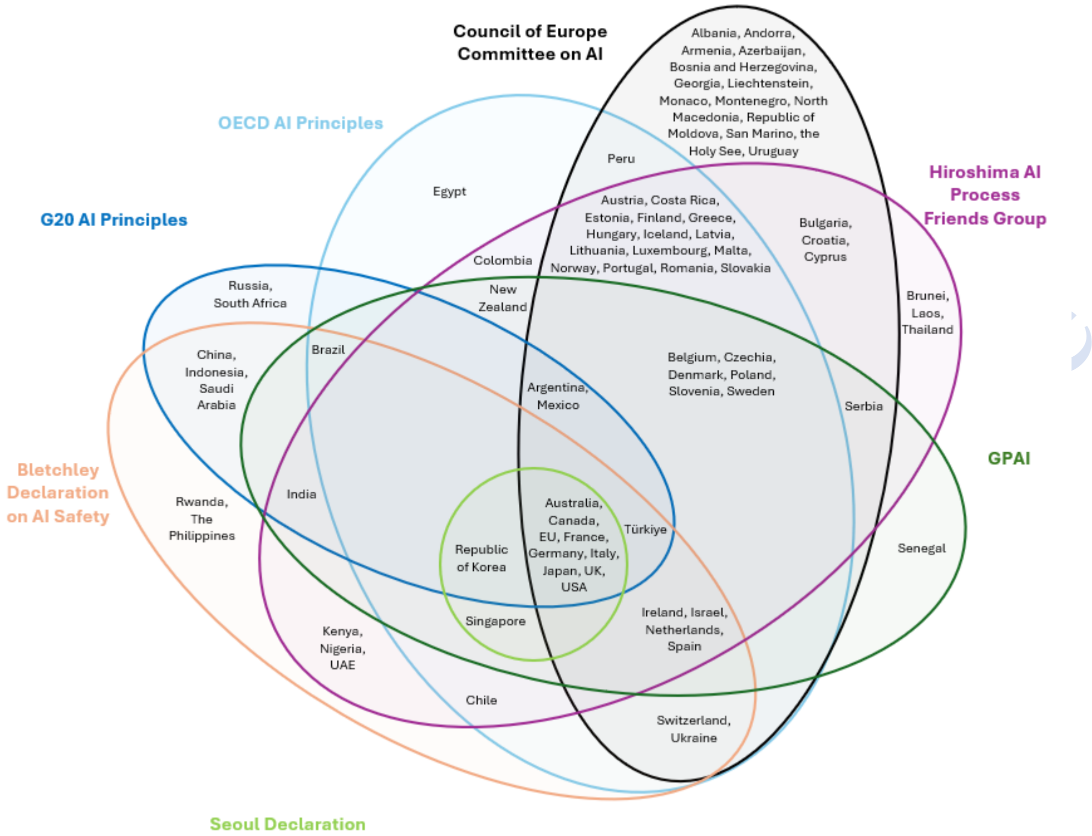
A 2022 study revealed three main themes throughout most of the existing global data governance frameworks: trust, individual rights and interests, and public interest. However, it also highlighted that despite sharing similar principles, governance frameworks show a high variation in definitions, purposes, approaches and scopes (Marcucci et al., 2023). There are no common global international treaties or resolutions related to the processing of data, although some privacy considerations are incorporated into human rights covenants, as reaffirmed by the Human Rights Council in 2019 (United Nations Human Rights Council, 2019). The fragmentation of global data governance presents challenges to the free data flow, cross-border collaboration, and the seamless functioning of digital services across national boundaries. Moreover, the underrepresentation of developing countries in global data governance discussion risks the formulation of standards and policies that do not fully address their unique needs and priorities, leading to less inclusive outcomes.[106]

The AI international governance ecosystem is also rather fragmented: in 2020 alone, there were over 160 AI governance frameworks in existence but not one common global set of guidelines. Intergovernmental groups and organizations including the G20, OECD, and the Council of Europe have attempted to create their own AI framework, and new AI-specific organizations have been set up to address this issue, including the AI Safety Summit, the Global Partnership on Artificial Intelligence (GPAI), and the Hiroshima AI Process Friends Group. In addition to these international efforts, a series of regional initiatives tries to promote coordination and interoperability, including the Santiago Declaration to promote ethical AI in Latin American and Caribbean, the African Union Continental Strategy, the ASEAN AI Guide, and the European AI Act. The latter is the only one of these initiatives to be binding, in accordance with EU governance frameworks and the GDPR.

Many of these global initiatives for data governance and AI regulation share common goals and themes, including focuses on human rights, risks, ethics, and trustworthiness. They highlight the urgency of addressing potential risks and call for enhanced global collaboration to harness AI potential for sustainable development while safeguarding against dangers and uncertainty. However, most participating countries in these AI frameworks are from the Global North, with limited participation from the Global South, despite the enormous potential impact of AI on their economies, societies and citizens (Figure 10).

[106] https://unctad.org/publication/data-development

Figure 10: The involvement of countries in global AI governance



Source: UNCTAD elaboration.

The limited participation of developing countries in global discussions about such questions threatens the success of an inclusive digital transformation and fails to account for their roles in the frontier technology value chain. This is also evidenced by the fact that many of these frameworks do not address the primary challenges to a technology-led economic diversification in developing countries outlined in the previous chapter (i.e., infrastructure, data, skills, among others). These challenges require coordinated efforts from the international community, and governance frameworks can do more than defining abstract principles.

In 2022, UNESCO released the AI Ethics Recommendations, while in 2023 the Human Rights Council passed a resolution reinforcing the relationship of digital technologies and human rights (United Nations Human Rights Council, 2023) and in 2024, the UN General Assembly adopted two new resolutions on AI and the Global Digital Compact (GDC) as an annex to the Pact of the Future, the main outcome of the Summit of the Future. The GDC aims at providing an inclusive approach to data and AI governance, supporting digital public goods and digital public infrastructure, fostering an inclusive, open, safe and secure digital space, advancing interoperable data governance and international governance of AI for the benefit of humanity.

For the past 20 years, the World Summit on the Information Society (WSIS) has been striving to build a people-centred and inclusive information society to harness the potential of information and communication technologies for sustainable development. This is supported by the work of UNCTAD and the CSTD on the digital economy. Recognizing the importance of global data governance in a world of accelerated digitalization, member States, in the Global

Digital Compact, have requested the CSTD to establish a working group to hold a multi-stakeholder dialogue on the fundamental principles of data governance. The CSTD is encouraged to report on the progress of this work at the 81st session of the UN General Assembly.

VI. Conclusion and recommendations

Fuelled by continuous technological advancements, the expansion of digital platforms has driven the transition to digital economy that revolutionized the economy and society. It has also shifted the focus of economic diversification from export-oriented industrialization to technology-led transformation. To address the shift in value creation towards knowledge and supporting technology-led diversification, industrial and STI policies should converge to favour the adoption and development of frontier technologies as well as the dissemination and creation of knowledge.

The rapid pace of digitalization boosts productivity and fosters new industries. However, it also poses challenges for developing countries, such as eroding the comparative advantage of low-cost labour and widening the productivity gap between developed and developing countries. Without proactive policy measures to harness the benefits of digitalization and frontier technologies, developing countries risk falling further behind, as occurred during previous industrial revolutions.

In this regard, developing countries are encouraged to:

- **Strategically position themselves to seize the opportunities offered by digitalization**: Governments should engage stakeholders to identify the potential applications of digital technologies across the economy that can favour economic diversification and industrial upgrading. Instead of a top-down approach, an open and iterative process helps ensure an efficient feedback mechanism and build consensus among stakeholders. Priority should be given to opportunities that align with the national development agenda, such as job creation or the green transition, while considering existing technological and productive capacities. A thorough technology assessment can help assess the opportunities and challenges of different technologies.
- **Develop national strategies for digital technologies**: Governments should formulate national strategies to leverage digital technologies, articulating clear visions and feasible roadmaps of their applications in the economy; this includes defining priorities and expected results, as well as identifying actions for future development. Apart from sectoral policies, a stronger emphasis should be put on improving data governance and innovation ecosystem which are becoming increasingly important in the digital economy. A whole-of-government approach is needed to ensure the alignment of digital and STI strategies and policies with other domains, such as the industrial and environmental spheres.
- **Diversify into digital products and services:** Government should invest in the creative economy and knowledge industries that can thrive in a digital environment. For example, governments could expand access to digital financial services, such as mobile banking, to promote financial inclusion and support entrepreneurial activities. Governments could also promote the growth of e-commerce platforms to facilitate trade and access to global markets, especially for SMEs.
- **Build robust digital infrastructure**: An accessible, affordable, and high-quality digital infrastructure is essential to provide digital connectivity and computing power to support the adoption and development of digital technologies. Government could mobilize investments from both public and private sources to create DPI systems such

as digital payment and cloud services to drive technology-led structural transformation and industrial upgrading.

- **Promoting digital literacy and skills development**: Governments should prioritize the education and training to diffuse digital literacy. Governments should also provide reskilling and upskilling programmes to help the workforce leverage digital technologies, improve productivity, and support the transition to new occupations and tasks brought about by digitalization and economic diversification.
- **Strengthen public-private partnerships**: Public-private partnerships offer significant potential to accelerate the development of digital infrastructure, enhance capacity-building, generate quality employment, as well as speed up the innovation process. While lessons from managing existing public-private partnership projects could inform these efforts, it is essential to strike a balance between competitive and unconditional grants, as well as between project-based and program-based support to safeguard public interest.
- **Establish regulatory frameworks**: Governments should establish clear and supportive regulations for digital technologies and digital businesses, including AI governance, data protection laws, cybersecurity frameworks, and intellectual property rights.

To support developing countries in adopting and developing digital technologies for economic diversification, the international community could consider the following recommendations:

- **Promote knowledge and experiences exchange**: International dialogues, global networks of exchange, and the CSTD studies and meetings are useful platforms for sharing good practices and lessons learnt on how to harness digital technologies for economic diversification. Exchange of knowledge and experiences can further facilitate collaboration across countries to accelerate technology adoption and promote innovation.
- **Enhance capacity-building activities**: The international community can support developing countries in creating strong educational and lifelong learning frameworks that integrate digital skills into current curricula and offer customized training programs based on the degree of automation and augmentation in various occupations. In addition, R&D partnerships among governments, academia, and industries could advance research and technological skills of stakeholders in developing countries.
- **Create technical cooperation projects**: The international community could implement technical cooperation projects to promote the adoption and development of digital technologies for economic diversification in developing countries. For example, the CropWatch Innovative Cooperation programme that leverages satellite data to monitor crop conditions for better agricultural management in developing countries.[107] These projects should address the needs and priorities of developing countries, considering the local economic context and technological capacities. The CSTD could serve as a platform to facilitate global STI partnerships, hosting expert meetings on shared STI priorities and consolidating cooperation experiences.

[107] https://unctad.org/project/cropwatch-innovative-cooperation-programme.

- **Set up a global open innovation strategy**: Open innovation approaches, including open data and open source, can help sharing knowledge and resources as well as and improve transparency and trust, thereby enabling global collaboration and innovation. A global open innovation strategy can set clear direction and principles to guide technological development and address global challenges effectively. In this respect the UN can act as a bridge between different international initiatives for open innovation and boost their impact at the global scale.
- **Empower policymakers in designing and implementing STI policy**: Capacity building and training help policymakers in developing countries improve awareness and understanding of different policy instruments and incentives. It is particularly important to share international good practices and knowledge on how to bridge STI and industrial policies. The international community, including through the CSTD, could also support developing countries to implement technology assessment, including on how to assess new technologies on the multilateral level.
- **Support infrastructure development**: The international community should support investments in national infrastructure development, in particular digital connectivity and computing power, that enable the deployment of digital technologies in production processes for economic diversification and industrial upgrading. The international community could scale up collective actions on DPI, from formulating principles and governance structure to supporting developing countries to implement DPI systems based on the local needs and priorities.
- **Develop global consensus on ethical frameworks and guidelines**: The rapid technological advancement, especially the rise of AI and big data analytics, calls for clear ethical frameworks and guidelines to prevent misuse and uphold human rights. The international community should enhance global cooperation to develop and align ethical frameworks and guidelines for the responsible adoption of digital technologies.

Annex: Suggested questions for discussion during the Intersessional Panel of the Commission

To facilitate the discussion at the Intersessional Panel, below presents a set of questions for consideration:

1. What are the specific challenges and opportunities brought by frontier technologies to countries at different levels of development targeting economic diversification? How to address the disproportionate challenges for least developing countries?
2. What is the role of industrial and innovation policies for economic diversification in a world of accelerated digitalization? How should the strategy and instruments be revamped to account for the shift in value creation towards data and services and support technology-led diversification?
3. Which are examples of effective and inclusive policies for innovation and economic diversification in the digital era that can inform strategies in developing countries?
4. How to improve the readiness of developing countries, especially in terms of infrastructure, data, and skills, to utilize digitalization to diversify their economies?
5. How to leverage international cooperation to ensure that industrial policies implemented in a world with uneven technological capabilities and varying development priorities benefit all and do not worsen inequality?
6. How to induce an inclusive digital transformation that enhances countries' productive capabilities and what role the CSTD might play in supporting it?

References

Agrawal A, Kapur D, McHale J and Oettl A (2011). Brain drain or brain bank? The impact of skilled emigration on poor-country innovation. *Journal of Urban Economics*. 69(1):43–55.

Altenburg T (2011). *Industrial Policy in Developing Countries: Overview and Lessons from Seven Country Cases*. Discussion paper / Deutsches Institut für Entwicklungspolitik, No. 4/2011. Deutsches Institut für Entwicklungspolitik. Bonn.

Arza V, López A, Montes-Rojas G and Pascuini P (2023). In the name of TRIPS: The impact of IPR harmonisation on patent activity in Latin America. *Research Policy*. 52(6):104759, Elsevier.

Bentley SV, Naughtin CK, McGrath MJ, Irons JL and Cooper PS (2024). The digital divide in action: how experiences of digital technology shape future relationships with artificial intelligence. *AI and Ethics*.

Bernier A, Molnár-Gábor F and Knoppers BM (2022). The international data governance landscape. *Journal of Law and the Biosciences*. 9(1):lsac005.

Chandy R, Hassan M and Mukherji P (2017). Big Data for Good: Insights from Emerging Markets*. *Journal of Product Innovation Management*. 34(5):703–713.

Collingridge D (1982). *The Social Control of Technology*. St. Martin's Press. New York.

European Parliament and Council of the European Union (2016). *Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 - on the Protection of Natural Persons with Regard to the Processing of Personal Data and on the Free Movement of Such Data, and Repealing Directive 95/46/EC (General Data Protection Regulation)*.

Evenett SJ (2019). Protectionism, state discrimination, and international business since the onset of the Global Financial Crisis. *Journal of International Business Policy*. 2(1):9–36.

Ferraz D, Falguera FPS, Mariano EB and Hartmann D (2021). Linking Economic Complexity, Diversification, and Industrial Policy with Sustainable Development: A Structured Literature Review. *Sustainability*. 13(3):1265, Multidisciplinary Digital Publishing Institute.

Fietz K and Lay J (2023). Digital Skills in the Global South: Gaps, Needs, and Progress. German Institute for Global and Area Studies. Hamburg, Germany. (accessed 26 August 2024).

Foray D (2006). *The Economics of Knowledge*. The MIT Press. Cambridge, MA.

Hausmann R, Hwang J and Rodrik D (2007). What you export matters. *Journal of economic growth*. 121–25, Springer.

Hidalgo CA and Hausmann R (2009). The building blocks of economic complexity. *Proceedings of the National Academy of Sciences*. 106(26):10570–10575.

Imbs J and Wacziarg R (2003). Stages of diversification. *American economic review*. 93(1):63–86, American Economic Association.

International Telecommunications Union (2023). Measuring digital development: Facts and Figures 2023. Facts and Figures. International Telecommunications Union. Geneva, Switzerland.

International Telecommunications Union (2024). The ICT Development Index 2024: Measuring digital development. International Telecommunications Union.

Jacobs J (1969). *The Economy of Cities*. Random House. New York.

Kojima K (2000). The "flying geese" model of Asian economic development: origin, theoretical extensions, and regional policy implications. *Journal of Asian Economics*. 11(4):375–401, Elsevier.

Lee H-P (Hank), Yang Y-J, Von Davier TS, Forlizzi J and Das S (2024). Deepfakes, Phrenology, Surveillance, and More! A Taxonomy of AI Privacy Risks. *Proceedings of the CHI Conference on Human Factors in Computing Systems*. CHI '24Association for Computing Machinery. New York, NY, USA: 1–19.

Lucas Jr RE (1988). On the mechanics of economic development. *Journal of monetary economics*. 22(1):3–42, Elsevier.

MacFeely S (2020). In search of the data revolution: Has the official statistics paradigm shifted? *Statistical Journal of the IAOS*. 361075–1094.

Marcucci S, Alarcón NG, Verhulst SG and Wüllhorst E (2023). Mapping and Comparing Data Governance Frameworks: A benchmarking exercise to inform global data governance deliberations. The Governance Lab.

Meyer J-B and Brown-Luthango M (1999). Scientific Diasporas: A New Approach to the Brain Drain. *Management of Social Transformations (MOST) Program*.

Nakanishi T and Hori S (2023). Data Free Flow with Trust: Overcoming Barriers to Cross-Border Data Flows. Briefing Paper. World Economic Forum. Geneva, Switzerland.

OECD (2017). *Development Co-Operation Report 2017: Data for Development*. Development Co-operation Report. OECD. Paris.

OECD (2024). Framework for Anticipatory Governance of Emerging Technologies. OECD Science, Technology and Industry Policy Papers No. 165. (accessed 25 June 2024).

Roberts T and Hernandez K (2019). Digital Access is not Binary: The 5'A's of Technology Access in the Philippines. *The Electronic Journal of Information Systems in Developing Countries*. 85(4):e12084.

Rodrik D (2004). Industrial Policy for the Twenty-First Century. United Nations Industrial Development Organization. (accessed 5 March 2024).

Roudgar I and Richards C (2015). The policy challenge of the global brain drain: addressing the dilemmas of contributing push-pull factors. *International Journal of Public Policy*. 11(1/2/3):73.

Semiconductor Industry Association (2024). 2024 Semiconductor Industry Association Factbook. Semiconductor Industry Association.

Stephany F, Kässi O, Rani U and Lehdonvirta V (2021). Online Labour Index 2020: New ways to measure the world's remote freelancing market. *Big Data & Society*. 8(2):20539517211043240, SAGE Publications Ltd.

Stiglitz JE (1989). Markets, market failures, and development. *The American economic review*. 79(2):197–203, JSTOR.

The United Nations Secretary-General's Independent Expert Advisory Group on a Data Revolution for Sustainable Development (IEAG) (2014). A World that Counts: Mobilising the Data Revolution for Sustainable Development. United Nations.

UN and ILO (2024). Mind the AI Divide: Shaping a Global Perspective on the Future of Work. United Nations. New York, NY, USA.

UNCTAD (2024a). Data for Development. Technical and statistical report No. UNCTAD/DTL/TIKD/2024/2. United Nations. New York, NY, USA.

UNCTAD (2024b). Digital Economy Report 2024: Shaping an environmentally sustainable and inclusive digital future. Digital Economy Report. United Nations Conference on Trade and Development. New York, NY, USA.

United Nations (2022). *E-Government Survey 2022: The Future of Digital Government*. United Nations e-government survey, No. 2022. New York.

United Nations Conference on Trade and Development (2023). Technology and Innovation Report 2023: Opening green windows - Technological opportunities for a low-carbon world. Technology and Innovation. United Nations Conference on Trade and Development. Geneva, Switzerland.

United Nations Human Rights Council (2019). *The Right to Privacy in the Digital Age*.

United Nations Human Rights Council (2023). *New and Emerging Digital Technologies and Human Rights*.