Bracing for the New Industrial Revolution

Elements of a Strategic Response

Discussion paper

For reference and citation, please use: United Nations Industrial Development Organization, 2019. *Bracing for the New Industrial Revolution: Elements of a Strategic Response*. Vienna.

CONTENTS

The fourth industrial revolution: Opportunities, challenges and risks

We are on the verge of the fourth industrial revolution (4IR, also referred to as Industry 4.0). Driving the 4IR forward are rapid advances in digital technologies—artificial intelligence (AI), machine learning, robotics, additive manufacturing (3D printing), the Internet of Things (IoT), distributed-ledger technology (DLT) or blockchain, and quantum computers—and their integration with biotechnology, nanotechnology and cognitive, social and humanitarian sciences (known as convergent and nature-like technologies). These technologies are also referred to as frontier technologies because they are innovative, fast-growing, deeply interconnected and interdependent.

The convergence of previously fragmented and disconnected scientific disciplines and technologies is self-enforcing, advancing science, technology and innovation, entrepreneurship and structural transformation. A recombination of complex technology ecosystems and cross-sectoral spillovers is creating new fields of knowledge, scientific disciplines, technology, materials and activities and has the potential to address pressing global challenges—such as aging populations in developed countries, rapid population growth in Africa and least developed countries (LDCs), food security, healthcare and medicine, environmental degradation and climate change—and to ensure access to energy and education to all.

The 4IR is leading to a paradigm shift that is profoundly altering how we work, live and interact. Nature-like schemes that can be reproduced, as well as newly created advanced materials with properties similar to those found in nature, are already transforming manufacturing, energy production and storage. Advances in AI capabilities have greatly enhanced computer vision, speech recognition, motor control (of robots), language translation, online search engines, social media platforms and decision-making processes in science, finance and other fields. The capability of AI to mimic aspects of human intelligence, such as pattern recognition and judgment, is a historic advance in automation. Breakthroughs in genetics, nanomedicine, personalized medication, 3D imaging diagnostics and human organ development and transplantation promise to extend lifespans and transform human well-being.

The 4IR is the fastest period of innovation ever experienced. Innovation is becoming more complex, multidisciplinary, collaborative, unplanned, unpredictable and disruptive. It is developing at an exponential rather than linear pace. Innovation cycles are accelerating and shortening, collapsing the product lifecycle. The implications are widespread and systemic. The exponential technological progress of the 4IR will affect all countries, especially LDCs. Digital and convergent technologies are merging the physical, digital and biological worlds, affecting all socio-economic sectors and scientific disciplines and blurring the differences between them. We are already witnessing the industrialization of agriculture (removing the limits of land and of decreasing returns to scale), the "servitization" of manufacturing (manufacturing products coupled with services), the convergence of once separate industries, and the industrialization of services (service providers entering manufacturing).

Blockchain and related technological changes have the potential to disrupt socio-economic systems. They create relations and processes with the use of smart contracts, which enable timely execution and efficiency, thus decreasing human error and even challenging the role of markets and governments. The trends in financial technology (fintech) point to the possibility of transferring social trust from institutions backed by governments, to systems that rely on clearly defined codified inputs, such as data, assets, value of goods and services.

Expected economic, environmental and social benefits

Economic benefits

The economic benefits of 4IR technologies come from increased revenues due to lower transaction costs, greater control over production processes, more reliable and better quality output, increased productivity and competitiveness, greater industrial safety, better product quality and more customer involvement in production.

Global value chains (GVCs), now functionally and physically fragmented, can be advanced by smart, digital networking and cyber-physical systems, allowing for horizontal and vertical networking in the value chain and for management of these processes in real-time across great distances. This will make the creation of intelligent production systems possible that enable a shift from mass production to mass customization at the unit price of mass production.

4IR technologies can enhance product–service characteristics and functionalities—including product innovation, customization and time to market. Data analytics, for instance, allow taking advantage of collecting and analysing real-time customer data, enabling the direct involvement of customer demands and facilitating cost-effective mass customization of products. These insights into customer behaviour can provide enormous advantages for new products, services and solutions. The changes open new organizational and business model possibilities by attaching services to manufacturing production. In this way, 4IR technologies offer the possibility of revitalizing industrialization and boosting economic growth by creating new goods and by blending manufacturing and service activities.

4IR technologies can also improve production efficiency or reduce associated costs. The use of big data analytics, for example, provides real-time insights to improve production efficiency.

Increasing capital utilization is another channel for 4IR technologies to affect competitiveness. This is particularly important for firms operating in developing countries, where capital constraints can be a major barrier for upgrading technology. For fixed capital investments in machinery, tooling, intelligent automated systems, sensors and robots, 4IR technologies allow for improving the use of fixed assets, reducing idle times and increasing capacity use. In addition, more flexible robots or 3D printers can reduce investments in multiple automated production lines and the need for investment in tooling and retooling. Predictive maintenance can also bring benefits. The combination of networked robots, advanced sensors and machine learning allows for immediate self-diagnosis and fault detection, reducing machine down time and providing solutions quickly.

By supporting competitiveness and productivity gains, the adoption and diffusion of ADP technologies are expected to boost economic growth, job creation and poverty alleviation, thus contributing to some of the prime objectives of UN Agenda 2030, as reflected in the SDG 1 on poverty, SDG 8 on decent work and economic growth and SDG 9 on industry, innovation and infrastructure.

Countries leading in many frontier technologies will enjoy a competitive edge over those that are lagging in science, technology and innovation development. However, exponential technological change also creates unique opportunities for "latecomer" countries to catch up with more advanced countries. In the era of the 4IR, latecomer developing countries that are active and quick learners have more opportunities than ever to exploit the advantage of their late arrival by tapping into affordable 4IR technologies and creating new products and services, rather than having to reproduce previous technological trajectories. Some frontier technologies are becoming more affordable and embody knowledge that does not require high skill levels for use, and some do not require high capital investment. Thus, leapfrogging will be possible in some sectors and with some technologies.

Safety and security of data collection, ownership and transfer, enabled by blockchain/DLT can substantially contribute to higher efficiency and productivity. Blockchain/DLT can also enhance a reduction of negative externalities such as asymmetry in information and can enable equal access to markets for developing country producers. The distributed character of blockchain allows the direct communication and interaction of distant communities to equally participate in decision-making, both in the market and in society. Using trust-based technology enables avoiding unpredicted costs rising from fraudulent activities.

Applications of wireless innovation such as 5G technologies can reinforce benefits of 4IR technologies and can provide developing countries with opportunities to leapfrog.

Environmental benefits

The environmental benefits of 4IR technologies include greater resource efficiency and effectiveness, better access to electricity and water, reduced emissions of greenhouse gases and other pollutants, and better waste management. Whereas the first industrial revolution was based on the linear production model of processing resources from nature into final goods and then disposing them in landfills after consumption, creating unprecedented amounts of waste, the 4IR has the potential to eliminate waste. It supports effective circular economy business models that consume renewable material resources and keep materials from finite stocks in an infinite loop.

Through industrial IoT, for instance, manufacturers can control and analyse product performance while collecting usage data. In turn, the collected data may provide a foundation for circular economy business models. Business models geared towards recycling, remanufacturing or parts harvesting can also benefit from the collection of data on use and operations, providing more information on the condition of parts and thus increasing yields and reducing waste.

The application of 4IR technologies to manufacturing processes also opens opportunities for greater energy savings and energy efficiency. Energy savings can arise from optimizing or replacing energy-intensive technologies, from introducing new software tools that optimize energy use or from adapting business processes. Applying additive manufacturing to the production of parts and prototypes exemplifies the first case. For energy efficiency, introducing these technologies, along with 3D printing, may lead to significant energy savings beyond the industrial sector by introducing product innovations. Consider the increasing use of 3D-printed lightweight aircraft components by some manufacturers to reduce fuel consumption.

Technological breakthroughs in carbon capture and sequestration also have the potential to drastically reduce net carbon dioxide emissions and mitigate climate change. The new materials used in photovoltaic cells have great potential for energy efficiency and renewable energy technology. Biodegradable plastic offers a means of reducing plastic pollution, the second biggest threat to the environment after climate change. Geospatial data monitoring platforms, using advanced sensors and satellite imagery in combination with large-scale data analytics, enable tracking and monitoring of important environmental systems. The rapid development of satellites, drones and sensors, supplemented by intelligent AI algorithms and technologies, could provide a flow of data on greenhouse gas emissions in real time. This will significantly improve the transparency of monitoring, reporting and verification of data, which is critical to the accountability and effectiveness of global climate agreements.

Social benefits

The social benefits of 4IR technologies come from improvements in human cognition, health and physical capabilities; enhancements in creativity and innovation; advances in education and training systems; creation of a knowledge society; better food security and safety; greater worker safety; better access to food, sustainable energy and universal healthcare; and more opportunities for disadvantaged and vulnerable population groups, those who suffer from structural discrimination, such as women, children, older persons, persons with disabilities, ethnic minorities and indigenous peoples, as well as small and medium-sized enterprises (SMEs), to participate in global production and innovation networks as service providers or as producers of niche products.

4IR technologies can improve working conditions in industrial production by introducing new workflows and task allocations and can increase the skill threshold of the workforce. For instance, automation solutions in the automotive sector have offered opportunities for reorganizing production tasks and moving workers away from the most physically demanding tasks.

4IR technologies can also address the product needs of marginalized groups. These groups have been largely overlooked by manufacturing systems based on mass and lean production technologies, whose economic convenience stems from large volumes to lower unit costs. 4IR technologies make it possible to design and commercialize highly customized products at a lower price, as the diffusion of 3D printing provides a more economical option for low volumes of manufacturing. The production of high-quality medical devices at a more affordable price is a paradigmatic example.

Open education and knowledge access platforms enable the transfer of knowledge from creation to consumption quickly and efficiently. These platforms are especially beneficial for sections of the population who may get marginalized in the 4IR race, such as women and the elderly, as well as workers currently in jobs that have a high probability of disappearing.

Expected challenges and risks

Dealing with automation

Despite the great potential of 4IR technologies for productivity growth and competitiveness, some caution and moderation of expectations are warranted. The main concerns are associated with changes in the labour market and impacts on employment in the manufacturing sector.

In the debate on 4IR technologies and the future of work, one side focuses on the labour-saving potential of 4IR technologies. This idea is reinforced by the fact that these technologies have improved the performance of machines in fields that require nonroutine cognitive skills, expanding the set of activities that machines can perform effectively, such as natural language processing or image, video and speech recognition. Moreover, advances in the dexterity of robots have allowed them to perform more nonroutine manual. These changes could make it easier to substitute machines for human workers and reshape labour markets.

The other side notes that the effect of new technologies may also be transformative by complementing the work of humans, boosting productivity by facilitating the execution of some tasks or by enabling operations and processes that humans could not perform unaided. There is thus optimism for new job creation through the diffusion of 4IR technologies, driven by new occupations (software developers, data analysts) and by employment creation through increased industrial linkages.

Whatever the net employment impact of these different forces, what seems clear is that technological change is not neutral with respect to the profile of job skills demanded. Technological change tends to favour skills that are complementary to the new technology As the jobs created by 4IR technologies are likely to be more demanding of new and technical skills, as well as of analytic and cognitive abilities, mastering these skills will provide the best safeguard against displacement by technology. That presents major challenges to workers in developing economies, who must adapt to these changes in order to take advantage of the opportunities offered by 4IR technologies.

Even with lively policy and academic debates, there is still no clear-cut evidence on whether 4IR technologies in manufacturing will really make some occupations redundant or whether, instead, they will change the content of jobs without necessarily replacing human workers. 4IR technologies might also create occupations that never existed before.

Keeping GVC participation

Firms in developing countries may be harmed by the progressive diffusion of 4IR technologies in advanced economies. For advanced countries, the earlier drawbacks of lost manufacturing jobs could be softened by the expectations that 4IR technologies may bring production back (backshoring or reshoring) and reboost manufacturing production. New cheap capital machinery and robots replacing manual work could induce companies to return production to high-income countries close to big consumer markets. This phenomenon could counterbalance previous decades' extension of GVCs to decentralize production from high-income countries to lower-income countries for activities requiring low skills and low salaries, such as assembly-line production.

For developing countries, the lost relevance of cheap labour as a comparative advantage and the increased backshoring to industrialized countries could take away manufacturing and reduce employment creation. Beyond hypotheses and anecdotal examples, however, general evidence of actual backshoring is still scarce, so drawing conclusions on the ultimate impact on developing country employment and designing sound policies to address it is difficult.

Addressing the rebound effect

The 4IR technologies may produce a rebound effect. Some 4IR technologies can be accompanied by rising demand for scarce resources (such as certain metals) and increased consumption of energy. Greater use of sensors and connected devices also consumes energy.

While the Internet of Things (IoT) and continuous use of massive amounts of data leave an environmental footprint, fourth generation blockchain technology eliminates the need for massive energy consumption. Electric vehicles can reduce urban pollution and improve air quality, but the net mitigation effect will be limited if their batteries are charged with electricity generated by fossil fuels.

The potential of 4IR technologies therefore needs to be assessed from the perspective of material and energy efficiency and effectiveness, and circular economy (CE) approaches that apply regenerative and resource-maximization principles. Society must ensure that CE approaches are followed in the ecosystem of 4IR technologies by monitoring the energy and material-resource intensity of 4IR technologies and business models as well as the carbon dioxide emissions and toxicity of materials used. The implications of the 4IR for sustainability need to be researched properly, using multidisciplinary and multi-stakeholder partnership approaches.

Accounting for differences in how industrial sectors are affected

The impact of 4IR technologies will differ across and within sectors because of sectoral differences in the scope of opportunities offered by 4IR technologies for value chain innovations (products, processes and functions) and implementation of new business models. Different industrial sectors need different types of technological building blocks, collection and management of data for innovation and thus face different challenges with respect to data and technology access and use. Absorption capacities for 4IR technology also vary by industry and even by enterprise, and consequently the maturity and readiness for adoption and diffusion will differ for different 4IR technologies.

Generic models for assessing maturity and readiness for adoption and diffusion of the 4IR technologies may be useful as a general framework but will require testing for their usefulness for implementation on the ground. Industry maturity and readiness approaches need to be tailored to individual industrial sectors and on the macro level to specific country contexts. Multidisciplinary teams can create pilot projects that address aspects of readiness and maturity for specific industries: horizontal and vertical integration, data quality protection, relevant 4IR technologies; industrial safety, security and suitability; inclusiveness of stakeholders, such as suppliers, customers, research institutions, workers and managers; human skills; cultural aspects; strategies and policies; and sectoral innovation systems. Research needs to test the usefulness of these models for diagnostics, roadmapping and roadmap implementation. The same holds at the enterprise level. One example of enterprise readiness indexes includes Singapore's Smart Industry Readiness Index.

Ensuring industrial safety

Securing industrial safety and security is challenging. Collaborative robot safety is one such challenge; the occupational risk of additive manufacturing is another. Nanotechnologies, new professions arising from industrial changes and potential psychological risks need to be researched from the perspective of occupational health and safety.

Many of the technological innovations installed in industrial sites are connected to the internet and become more vulnerable to cyberattacks on critical infrastructure and information technology–related disruptions. Smart manufacturing systems are more vulnerable to cyber threats and attacks as well as to armed drones or unmanned aerial vehicles (UAVs) with sophisticated intelligence guiding them. Drones can strike precise industrial targets with limited side effects and can be used for unequal fights between technologically advanced and far less advanced players. The complexity of these new technological systems and the increased risk of intrusion could result in substantial harm to production and even to the health of industrial personnel.

Security threats to data, intellectual property risks from cyber-espionage and cyber-terrorism between state and non-state actors are real and present. Security layers and secure computer coding systems are needed to reduce the vulnerability of industrial systems. Smart factories call for intelligent security responses and the leveraging of new technologies, such as blockchain, with the potential to improve computer security and manage the risks of new technologies.

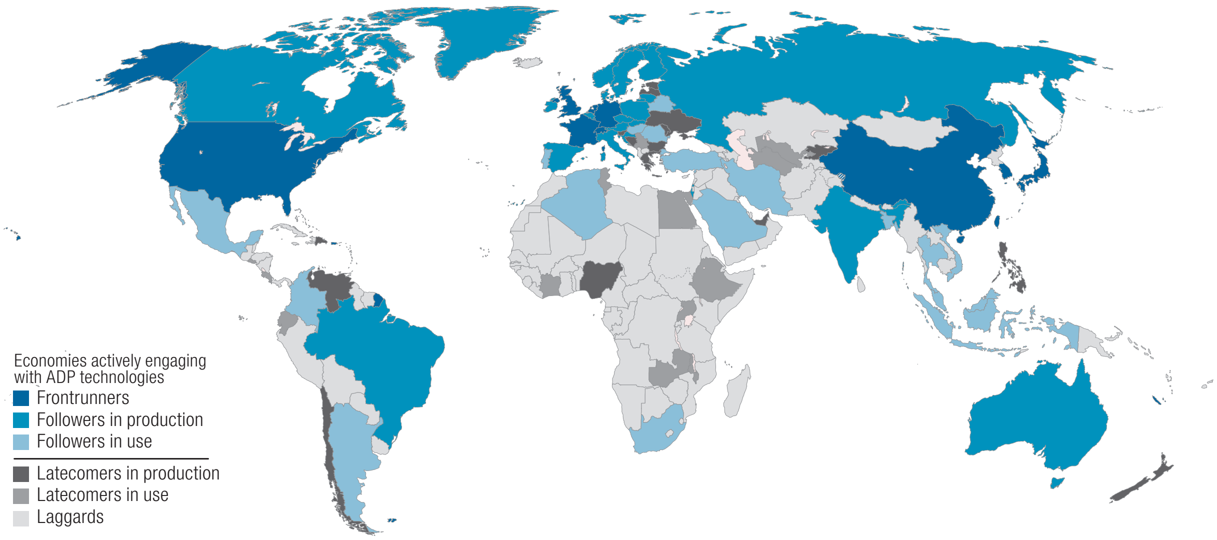
New approaches are needed to realize the potential of Industry 4.0 technologies to improve industrial safety. International organizations, governments, regulators and standard-setting bodies need to work collectively at a comparable pace to harness the benefits of these new technologies and ensure their safe and secure operation, to reduce any harm to individuals, the environment and industrial assets.

Narrowing the widening technology gap

New technologies are developing quickly, but they do not diffuse evenly. Countries with high capabilities in science, technology and innovation (STI) will be the first to reap the benefits of breakthroughs in frontier technologies. As a consequence, the technological gap between developed and developing countries will widen. Even developed countries with advanced STI capabilities will find it difficult to sustain their global competitiveness, if they underinvest in scientific research that translates into new products; industries; high value employment; skills in science, technology, engineering, and math (STEM); engineering talent; public–private partnerships in research and development (R&D); and linkages in global innovation networks.

A recent analysis conducted for the UNIDO Industrial Development Report 2020 indicates that the creation of advanced digital production technologies of the fourth industrial revolution remains extremely concentrated in a few economies. Combining patent and trade data, the analysis identifies groups of economies with different levels of engagement with these technologies. The main finding is that 10 economies—the frontrunners—explain 91 per cent of all global patent applications in this technological field and almost 70 per cent of the exports of capital goods associated to these technologies (see Figure 1)

FIGURE 1
The production and use of advanced digital production technologies is concentrated in a few frontrunners



Note: The map is presented solely for graphical illustration and does not express any opinion on the part of the UNIDO Secretariat concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. The category laggards also includes economies and territories not elsewhere classified. ADP is advanced digital production. Advanced digital production technologies (ADP) combine hardware (advanced robots and 3D printers), software (big data analytics, cloud computing and artificial intelligence) and connectivity (the Internet of Things). Advanced digital production technologies are the latest evolution of digital technologies applied to production, a core technological domain associated with the fourth industrial revolution. They give rise to smart production — also referred as the smart factory, or Industry 4.0.
Source: UNIDO Industrial Development Report 2020 "Industrializing in the digital age".

Large parts of the world, especially on the African continent, are yet to enter in the new digital era. Even among the economies with some activity in 4IR technologies, the roles are quite diverse. Latecomers, for instance, have already taken initial steps to engage with the new technologies, but it is not yet clear whether they will succeed in becoming followers. And among the followers, a large number are engaging in 4IR technologies by importing capital goods produced aboard, with very little or no domestic innovating and exporting activity. The prospects for these countries to move up the technological ladder are limited; advancing upward will require large investments in industrial and technological capabilities.

These features call for immediate action from the international community to support developing countries—especially the least developed countries—in adopting 4IR technological breakthroughs. Without international support, low-income countries run the risk of lagging further behind and failing to achieve the SDGs.

Yet another divide also exists within developing countries, where a large number of low-capability and low-performance actors coexist with more advanced ones. This divide between the most advanced companies and the rest has been defined as the digital capability gap. The gap's direct consequence is the creation of 4IR islands where a few major leading companies engaged with advanced digital production technologies operate in a sea of firms without capabilities and still using outdated technologies. Leading firms may be harmed by this gap, because they have trouble linking backwards and nurturing their supply chains. Thus, the gap turns a technology upgrading opportunity into a digital industrialization bottleneck.

Innovations in 4IR technologies emerge primarily in an open innovation model, at the junction of scientific fields, with the participation of private and public institutions in national and global innovation networks, and are based on the funding of basic and applied research and ecosystems building for knowledge exploitation (using a well-known thing) and exploration (exploring an unknown thing).

Given these trends, all countries will need to adopt a system of innovation and ecosystem perspective when designing their STI strategies and policies for ensuring a smooth transformation to the 4IR. Addressing this challenge requires a broad understanding of the key dynamics driving frontier technology innovation and diffusion and of the collective actions of society that are needed to deal with this issue.

Addressing the technology divide with developing countries

Many developing countries, especially LDCs, have low absorptive capacity to benefit from affordable 4IR knowledge and technologies. They still lack access to traditional and modern infrastructure (internet) and basic utilities, such as electricity, water and sanitation, as well as health services and technologies. Institutions are weak, creating a low-trust environment. Systemic opportunities for interactive learning are largely absent. There is still a lack of industry–academia collaborations; business environments are not conducive to technological learning, innovation and inclusiveness towards disadvantaged and vulnerable population groups and SMEs; and an embedded approach to industrial governance is weak or absent. These conditions put developing countries far behind developed ones in pursuing systems of innovation.

Strong R&D capacities and capabilities together with science and technology infrastructure are needed to operate on the technology frontier. These capacities and capabilities, common in developed countries, are often weak or absent in developing countries, where technological change takes the form mainly of acquiring new technology developed in industrialized countries. Therefore, acquiring and mastering technology developed elsewhere will play a key role in innovation and development in developing countries.

Developing countries must overcome the persistent digital divide, build local institutions, modernize education, upgrade knowledge and skill bases and involve disadvantaged and vulnerable population groups and SMEs in the real economy, if they are to tap the potential of many frontier technologies. Furthermore, without equitable access to traditional and modern infrastructure, it will not be possible for developing countries to access new knowledge, technology, information and markets. Collaboration among industries, governments, universities, research organizations and civil society is needed to attain collective efficiency and foster technological learning and innovation of society.

Addressing the positive and negative externalities of the 4IR

Exponential technological progress is creating opportunities to realize economic, environmental and social gains and achieve the Sustainable Development Goals (SDGs). But it is also opening avenues for possible negative spillovers and externalities, such as threats of a rising technology gap that can marginalize some countries and population groups—resulting in job losses and rising unemployment for some workers—create cyber-security threats to industry and generate ethical concerns and threats to global peace and security arising from the military uses of new technologies.

Major scientific and technological breakthroughs have impacts beyond the country that produces the new knowledge. No country alone can harness the full potential of emerging technologies and mitigate the associated risks. Collective action by society at national and supranational levels is needed to address the trade-offs arising from 4IR technologies and to ensure that people are put at the centre. Likewise, global problems, whose solutions require the generation of new scientific and technological competencies, are not confined to their country of origin. Even if newly created knowledge and technology are affordable, developing countries may not benefit from them, especially in the short run. The low level of technological capabilities and skills and inadequate finance, education and infrastructure in developing countries often constrain the absorption of new knowledge generated elsewhere. The international community is still learning how best to address these opportunities and risks. Nations are increasingly interlinked as the globalization of innovation intensifies and both the benefits and the risks associated with technological change are transmitted across borders.

What should be done at the national level?

At the national level, countries have formulated strategies, policies and programmes for fostering the uptake of 4IR technologies (horizontal and vertical), adapting education systems and ensuring multi-stakeholder participation. Among these are countries in North America (Canada and the United States); Western Europe (Belgium, France, Germany, Italy, the Netherlands, Slovenia, Spain and Sweden); Asia (China, Japan, India, Indonesia, the Republic of Korea, Malaysia, Singapore and Thailand); Latin America (Brazil, Chile and Mexico); and Africa (South Africa).

Developed countries and leading participants in global value chains have an obligation to use their resources and technology to build absorptive capacity in developing countries, especially among SMEs and disadvantaged and vulnerable population groups, such as women, youth, people with disabilities, ethnic minorities and indigenous peoples, to enable them to participate in the real economy.

Developing countries that are lagging in technology development and adoption can benefit from a stock of freely available knowledge (neither secret nor legally protected), if they upgrade their absorptive capacity. To become active learners, they need to invest massively in human resources in order to scrutinize, choose, modify, improve and apply that stock of knowledge. They must also invest in mainstreaming their science, technology and innovation (STI) strategies and policies for a smooth transformation to the 4IR. Additionally, they should use the 4IR concept as a tool to mobilize collective actions for addressing new ways of collaboration, innovation, and production and consumption.

What should be done at the multilateral level?

To meet the challenges and reap the benefits of 4IR technologies, the international community must also act promptly to ensure a smooth transition at international and national levels. Without concerted efforts by governments, businesses, academia and the international community, the potential of advanced technologies to realize the SDGs, especially SDG 9 on industry, infrastructure and innovation, will not be realized.

International organizations set common standards that allow all countries to benefit from best practice knowledge and transmit new knowledge. Specialized agencies like UNIDO play a crucial role in enabling countries to acquire competencies. By convening countries in a multilateral context, specialized international organizations provide important learning opportunities for the exchange of knowledge, not only from developed to developing countries, but also among developing countries. These can also leverage the power of multi-stakeholder partnerships across the international system, academia and business. Furthermore, multilateral development aid contributes to the transmission of technological expertise.

International organizations like UNIDO also have an institutional mandate to facilitate the diffusion of knowledge, and developed countries should pursue policies that promote knowledge transfer. A successful strategy for new technology transfer from developed to developing countries needs to consider both the generation and the transfer of newly created knowledge.

Collective action is thus vital for addressing the future of work and ensuring that 4IR technologies create prosperity for all people and all nations, leaving no one behind. Thematic areas for intervention at the multilateral level should include the following:

- Addressing political economy aspects of the 4IR, such as income redistribution, the relationship between labour and capital, taxation and universal basic income.
- Addressing the need for new regulations, standards, norms and conventions.
- Mitigating the potential risks of the 4IR through international agreements.
- Developing metrics to monitor progress on the uptake of 4IR technologies at the global, regional and sectoral levels.
- Addressing 4IR technology standards and operating systems for interoperability.
- Crafting an intellectual property rights regime that balances incentives for innovation with the greater need for technology diffusion in the 4IR era.
- Mitigating potential negative regional spillovers of new technologies and ensuring that the opportunities made possible by the 4IR can be leveraged to realize inclusive and sustainable economic development.
- Safeguarding data ownership and security as increasing amounts of data are created, by reinforcing cyber-security and regulations on data management.
- Ensuring the reliability and stability of cyber-physical systems and data management.
- Promoting the mainstreaming of national, regional and sectoral innovation systems as preconditions for successful 4IR technological learning, innovation and development, and addressing the challenge of the widening technology and innovation gap.
- Investing in capacity building to increase the absorptive capacity of developing countries for 4IR technologies.
- Fostering more effective international cooperation in ensuring that advances in frontier technologies place people at the centre.
- Ensuring that advances in frontier technologies meet universal ethical and moral standards and that competition in the technology sector is fair.
- Bringing frontier technologies to those who lack the means to access them by ensuring greater international cooperation on the generation, diffusion and adoption of frontier technologies, including wireless technologies, reflecting shared and differentiated responsibilities among all actors.
- Creating jobs through SME development as well as start-up and accelerator programmes in new technologies, and providing training for skilling and upskilling.
- Building awareness of the opportunities of 4IR technologies through research and policy advice and global fora events.
- Optimizing the use of knowledge and technology tools to build, develop and scale up distributed collaborative organizations and platforms for efficient and effective implementation of the above measures, thus decreasing the gap between developed and developing countries.
- Fostering partnerships in awareness-raising activities to better understand benefits of 5G technologies, test them in developing countries, grasp how to deal with cost-effective infrastructure and operational complexity stemming from the intersection between 2G/3G/4G and 5G technologies and study how to properly address standards and regulatory issues for 5G deployment.

The vision and mission of UNIDO's strategic approach

The 4IR frontier technologies have the potential to effectively address pressing global challenges and create opportunities to realize the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) and targets. These technologies are rapidly improving and are becoming increasingly available and affordable for use in industry in developing countries (in the agrofood system, energy creation and supply, and manufacturing, as well as for realizing the circular economy), but their absorption is not without challenges and risks.

UNIDO's vision

As a leading UN agency with a mandate to foster inclusive and sustainable industrial development (ISID), UNIDO leads the way in addressing opportunities, challenges and risks stemming from the 4IR and how these can affect inclusive and sustainable industrial and economic development.

UNIDO's mission

As a convener, knowledge and partnership broker, policy advisor and provider of technological solutions, UNIDO enables a smooth transformation towards the 4IR for countries with different levels of economic development, ensuring that no one is left behind. As a specialized agency of the UN system, its mission is to foster ISID, including through the development, transfer and adaptation of advanced technology on global, regional, national and sectoral levels.

Correspondingly, the mission underlying UNIDO's strategy for ensuring smooth transformation to the 4IR is based on the UNIDO constitution mandating its role in:

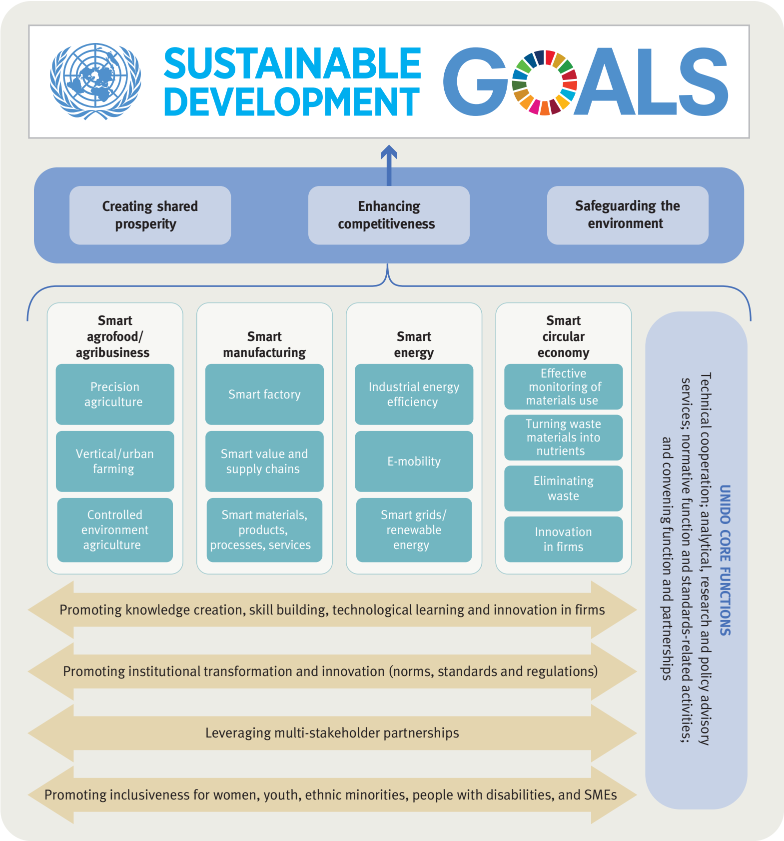
- Promoting and encouraging the development and use of new technologies.
- Assisting in the formulation of scientific and technological programmes and plans for fostering inclusive and sustainable industrialization in the new global economic setting.
- Serving as a repository and clearing-house for industrial information and collecting, monitoring, analysing and disseminating information on all aspects of industrial development on global, regional, national and sectoral levels, including the exchange of experience and technological achievements of developed and developing countries.
- Promoting, encouraging and assisting in the development, selection, adaptation, transfer and use of new industrial technology, taking into account the socio-economic conditions and specific requirements of the country and industry concerned, with special reference to the transfer of technology from industrialized to developing countries, as well as among developing countries.
- Organizing and supporting industrial training programmes to assist developing countries in providing the training needed to accelerate their industrial development.
- Assisting countries and international organizations in harmonizing standards to ensure cross-border operability of blockchain and distributed ledger technologies with the aim of simplifying international exchange and trade and minimizing risks.

UNIDO's thematic and cross-cutting areas

To achieve this vision and mission, UNIDO proposes to take action on the following strategic areas. Four thematic areas relevant for industrial development are (Figure 2):

- *Strategic Area 1.* Promoting smart agrofood: Addressing food security and incorporating disadvantaged and vulnerable populations and small and medium businesses through

FIGURE 2
UNIDO's 4IR thematic areas and cross-cutting issues



4IR technologies and circular economy models.

- *Strategic Area 2.* Promoting smart energy: Realizing efficiency and increasing the uptake of renewable energy through smart and artificial intelligence–based energy approaches.

- *Strategic Area 3.* Promoting smart manufacturing: Ensuring smooth transformations to smart manufacturing with an integrated and holistic portfolio of services.

- *Strategic Area 4.* Promoting the smart circular economy: Advancing the circular economy through research, communication, technology and standards.

Four cross-cutting strategic areas relevant for building capacity to absorb 4IR technologies are:

- *Strategic Area 5.* Promoting knowledge creation and commercialization, technological learning and innovation of firms, and skill building.

- *Strategic Area 6.* Ensuring the inclusion of disadvantaged and vulnerable population groups suffering from structural discrimination such as women, youth, older persons, persons with disabilities, ethnic minorities and indigenous peoples and promoting SMEs.

- *Strategic Area 7.* Building institutions: norms, standards and conventions.

- *Strategic Area 8.* Leveraging multi-stakeholder partnerships.

The thematic and cross-cutting strategic areas directly address the three pillars of sustainability (economic, environmental and social) and UNIDO's strategic thematic priorities: creating shared prosperity, advancing economic competitiveness and safeguarding the environment.

The development results are achieved through a mix of UNIDO's core complementary functions: technical cooperation; analytical and research functions and policy advisory services; normative function and standards-related activities; and convening function and partnerships for large-scale investment, knowledge and technology transfer, networking and industrial cooperation:

- Carrying out research to support evidence-based policy advice for ensuring smooth structural transformation to the 4IR.

- Convening and building multi-stakeholder knowledge platforms to address key issues related to the 4IR, such as setting up new norms and standards for interoperability, ensuring security and privacy, addressing loss of jobs and demand for new skills, and building multi-stakeholder partnerships for supporting uptake of 4IR technologies.

- Developing technical cooperation projects on the deployment of 4IR technologies for industrial modernization and upgrading, including advocating smart energy; addressing climate change mitigation; promoting the circular economy; ensuring industrial safety and security; addressing 4IR skills and gender gaps; and building the national, regional and sectoral innovation systems for the creation of new knowledge and its commercialization and for smart specialization.

- Strengthening strategic partnerships with a variety of development stakeholders, including governments, finance institutions, the business sector, United Nations entities, academia and civil society to leverage financial and technical resources to maximize UNIDO's development impact on the ground.