Bracing for the New Industrial Revolution

Elements of a Strategic Response

Discussion paper

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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 plat-

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 complemen-