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Industry 4.0 for inclusive development

Report of the Secretary-General

Summary

This report discusses industry 4.0 in manufacturing sectors and its impact on inequalities within and between countries. The use of industry 4.0 technologies in manufacturing can increase productivity and reduce the environmental impact of industrialization and may create rather than replace jobs. At the same time, most firms in developing countries are not ready to use such technologies; most continue to use analog technologies in production processes and need to further industrialize to benefit from industry 4.0. There is a risk of slow industrialization and dissemination of industry 4.0 in manufacturing in developing countries, further increasing inequalities between countries, and replicating the patterns seen in previous technological revolutions. Developing countries cannot afford to miss this new wave of technological change. Much will depend on national policy responses and partnerships. Each country requires science, technology and innovation policies appropriate to the level of development to prepare people and firms for a period of rapid change. This will require a balanced approach, building a robust and diversified industrial base while disseminating industry 4.0 technologies in manufacturing. It will also require forging and strengthening partnerships and international collaboration to facilitate economic diversification and technology dissemination and adoption by manufacturing firms in developing countries.

Introduction

1. At its twenty-fourth session, in May 2021, the Commission on Science and Technology for Development selected “Industry 4.0 for inclusive development” as one of its priority themes for the 2021–2022 intersessional period.

2. The secretariat of the Commission convened an intersessional panel meeting from 17 to 19 November 2021 to contribute to a better understanding of this theme and assist the Commission in its deliberations at its twenty-fifth session. This report is based on the issues paper prepared by the secretariat, the findings and recommendations of the panel and country case studies contributed by Commission members and United Nations entities.[1]

3. The impact of and responses to the coronavirus disease (COVID-19) pandemic have accelerated the dissemination of digital technologies in an era of already significant technological advances based on industry 4.0 technologies such as artificial intelligence, robotics and the Internet of things. The use of industry 4.0 technologies in manufacturing can help increase productivity and reduce the environmental impact of industrialization and may create more jobs than it replaces. At the same time, the adoption of industry 4.0 affects the relative productivity of firms in different sectors and economies, thereby impacting prospects for industrialization and structural transformation in developing countries, which are critical for inclusive development and the reduction of disparities within and across countries. This change in manufacturing also affects wages and employment opportunities due to differences in skills and prevailing disparities in education choices and options resulting from social contexts and personal characteristics such as age, gender and ethnicity. Developing countries need to design and implement policies to take advantage of industry 4.0 while minimizing potential adverse effects. The international community plays a role in facilitating economic diversification and technology adoption by manufacturing firms in developing countries.

I. Trends in industrialization, inequalities and effects of the pandemic

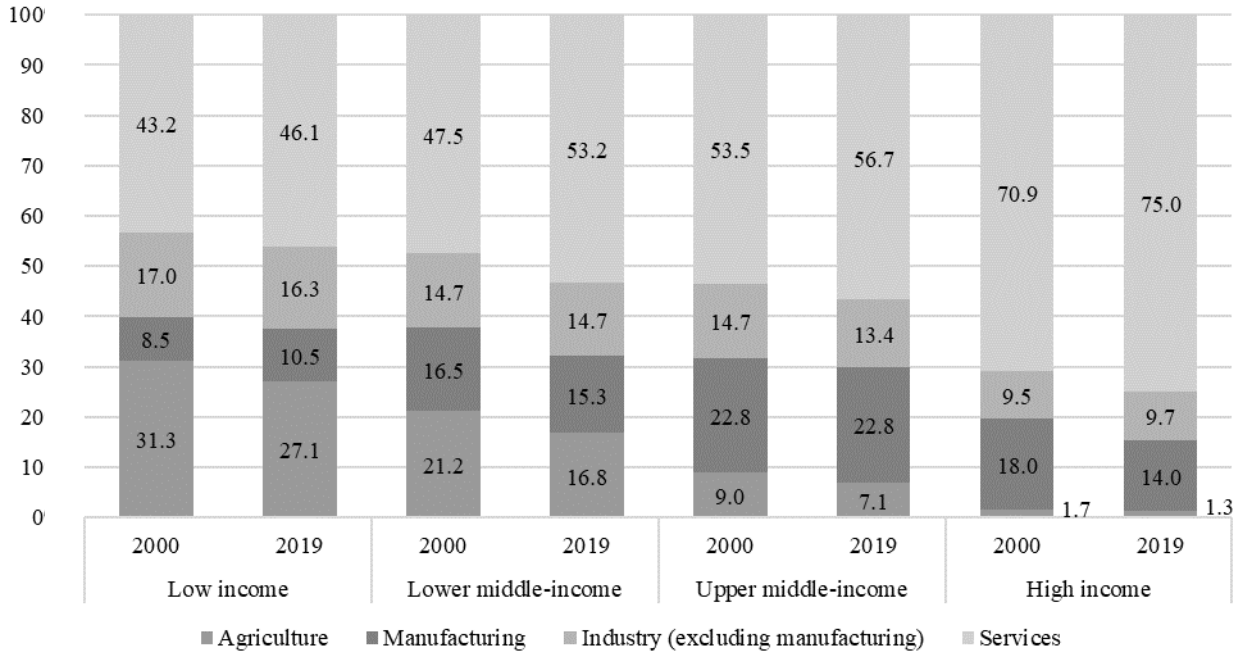
4. Each wave of technological progress since the industrial revolution has been associated with sharper inequalities between countries. Before the 1800s, there was little income disparity across countries; rather, inequality was a matter of domestic class divides. Currently, global inequality is defined by location, as the average gap in per capita income between developed and developing countries is over $40,000.[2] Over the past 40 years, within-country inequality has also increased in many countries, in some cases reaching significant levels. Historically, successful development has been associated with industrialization, technological upgrading and structural transformation, with shifts of output and employment from low value added activities, particularly subsistence agriculture, towards higher value added sectors of industry and services. Within industry, manufacturing offers better prospects for technological adoption and productivity growth, with spillover effects and the potential for higher wages in the whole economy. However, in the past two decades, on average, developing countries have followed a pattern of structural change characterized by a shift of value added and employment mainly from agriculture to services, with a minor increase or even a reduction in the share of

[1] Contributions from the Governments of Belarus, Belgium, Brazil, the Dominican Republic, Egypt, the Islamic Republic of Iran, Japan, Kenya, Latvia, Peru, the Philippines, Portugal, the Russian Federation, South Africa, Switzerland, Thailand, Turkey and the United Kingdom of Great Britain and Northern Ireland, as well as the Economic and Social Commission for Western Asia, the International Telecommunication Union, the United Nations Industrial Development Organization and the World Tourism Organization are gratefully acknowledged. For all documentation from the intersessional panel meeting, see https://unctad.org/meeting/cstd-2021-2022-inter-sessional-panel. *Note*: All websites referred to in footnotes were accessed in December 2021.

[2] United Nations Conference on Trade and Development (UNCTAD), 2021a, *Technology and Innovation Report 2021: Catching Technological Waves – Innovation with Equity* (United Nations publication, Sales No. E.21.II.D.8, Geneva).

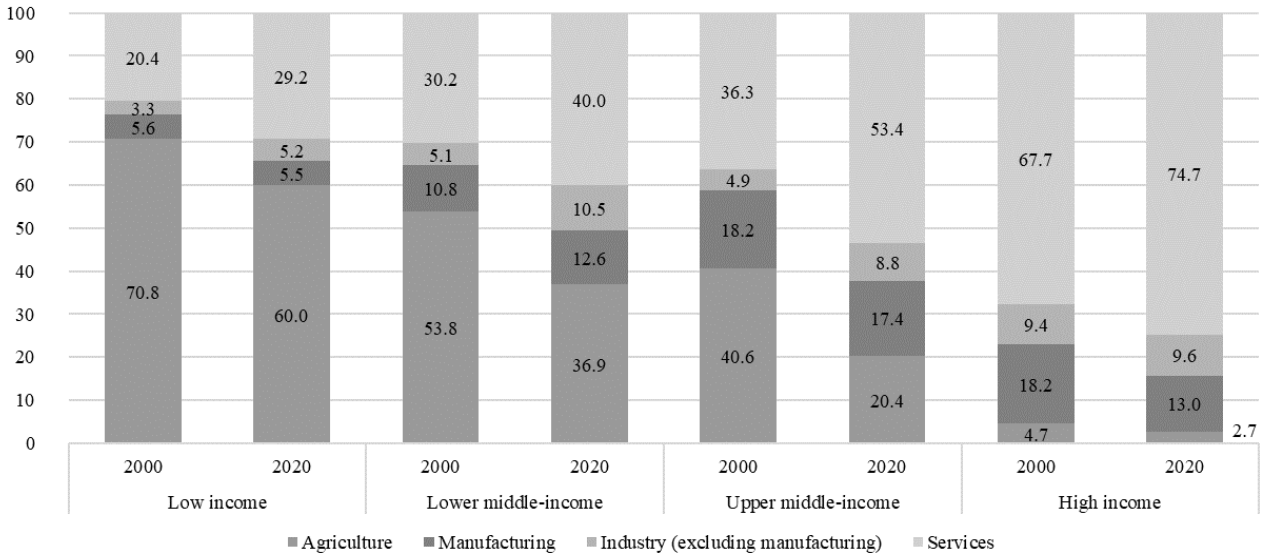
manufacturing value added in total gross domestic product (figures 1 and 2). This pattern shows slow industrialization in low-income countries and early deindustrialization in lower middle-income countries.

Figure 1
Share of gross domestic product by broad economic sector and income grouping
(Percentage)



Source: UNCTAD calculations, based on data from the UNCTADstat database.

Figure 2
Employment level, by broad economic sector and income grouping
(Percentage)



Source: UNCTAD, 2021a.

5. Foreign direct investment and global value chains have rapidly expanded since the 1990s. Global value chains account for some 80 per cent of international trade and most developing countries are increasingly participating in such chains; their share in global value added trade increased from 20 per cent in 1990 to over 40 per cent in 2013.[3] Declining costs of communications and trade have allowed for the segmentation of production processes, leading to the geographical diversification of production and complex cross-border supply chains. This expansion of production bases has often taken the form of multinational enterprises from developed countries taking advantage of lower labour costs and market access in developing countries through foreign direct investment. However, industrialization in developing countries has been uneven and slow. There is a mixed experience among developing countries in terms of technological learning through participation in global value chains, which depends on the governance of the chains, the levels of supplier competency and the maturity of national innovation systems. Firms in most developing countries tend to engage in fabrication, a lower-skill part of global value chains, and firms from more developed countries perform more research and development functions.

6. Human capital is essential for technological learning and innovation. This factor does not account on its own for the uneven and slow industrialization as, in most developing countries, worker skills have increased in the past two decades. In 2000–2020, the share of medium-skill jobs in developing countries increased by 6 percentage points in low and lower middle-income countries and by 10 percentage points in upper middle-income countries.[4] In the same period, the shares of high-skill workers increased in all countries, notably in middle-income countries, increasing by about 6 percentage points. However, structural factors affect where skills are employed; the bulk of the increase in medium-skill jobs has been in services and sales rather than manufacturing.

7. Given the continual differences in the economic structures of developing and developed countries, the productivity gap between these groupings has increased, from about $60,000 in 1991 to almost $90,000 in 2019.[5] Many developing economies are still predominantly agricultural and resources-based and there are significant gaps in productivity between the traditional and modern sectors in these economies. There is also a large informal economy in most developing countries (93 per cent of the world's informal employment), which is both a symptom and a factor of lower productivity.[6]

8. The pandemic is expected to increase job informality and insecurity. It has led to fewer jobs being available, longer gaps between jobs and reduced work hours, equivalent to a loss of 100 million full-time jobs in 2021 and 26 million full-time jobs in 2022.[7] The impact on manufacturing sectors depends on the production and trade structure in a country. For example, in Bangladesh, workers in microenterprises and small and medium-sized enterprises in the textile, apparel and leather sectors were more significantly affected by layoffs.[8] In Thailand, the pandemic could lead to the unemployment of 8.4 million people, 1.5 million of whom are in manufacturing, particularly in the malt beverages and automotive industries.[9] Firms in countries with high levels of unemployment and underemployment may have fewer incentives to adopt some industry 4.0 technologies to reduce labour costs, delaying their deployment.

[3] UNCTAD, 2013, *Global Value Chains and Development: Investment and Value Added Trade in the Global Economy* (United Nations publication, Geneva).

[4] UNCTAD, 2021a.

[5] Ibid.

[6] International Labour Organization, 2018, *Women and Men in the Informal Economy: A Statistical Picture* (Geneva).

[7] Ibid.

[8] United Nations Industrial Development Organization, 2021a, *Impact Assessment of COVID-19 on Bangladesh's Manufacturing Firms*, Vienna.

[9] United Nations Industrial Development Organization, 2021b, *Impact Assessment of COVID-19 on Thailand's Manufacturing Firms*, Vienna.

9. The pandemic has also significantly affected international investment flows. In 2020, global foreign direct investment fell by 35 per cent.[10] Developing economies were relatively resilient, with a decline of 8 per cent, mainly due to robust flows in Asia. The fall in flows across developing regions was uneven, with a drop of 45 per cent in Latin America and the Caribbean and 16 per cent in Africa. In the first half of 2021, foreign direct investment rebounded strongly, reaching an estimated $852 billion, but the recovery was uneven, with high-income economies more than doubling quarterly inflows and low-income economies experiencing a reduction of 9 per cent.[11] This slow recovery may reduce opportunities for these regions to benefit from foreign direct investment related to industry 4.0.

10. Private sector decisions regarding participation in global value chains may also be affected by experiences of the COVID-19 crisis. For example, one possible change is that reshoring might lead to shorter, less fragmented value chains and the geographical concentration of value added, primarily in higher technology-intensive sectors such as the automotive, machinery and equipment and electronics sectors. Reshoring could hinder the deployment of industry 4.0 technologies in developing countries, given that it is more likely to affect high technology-intensive sectors, which are the leading users of such technologies.

II. Industry 4.0: Concept and main characteristics

11. Industry 4.0 refers to the smart and connected production systems made possible by new technologies, particularly with the increased use of automation and data exchanges. Smart production integrates and controls production using sensors and equipment connected to digital networks supported by artificial intelligence. This entails new forms of interaction between humans and machines through the combination of traditional and new technologies under three main components, namely, hardware, software and connectivity. The hardware component comprises modern industrial robots, cobots (robots that work in collaboration with humans and that are easily reprogrammable and used in several industries for various tasks, such as packaging, palletizing and the automated operation of industrial machine tools in a manufacturing plant), intelligent automated systems, three-dimensional printers for additive manufacturing and traditional and less technologically advanced machinery, equipment and tools. Such technologies are not new to manufacturing; it is the other components, namely, software and connectivity, that make smart production different. The software component comprises more traditional information and communications technology (ICT), such as enterprise systems, computer-aided manufacturing, computer-integrated manufacturing and computer-aided design, as well as data analytics based on big data and artificial intelligence. Digital networks, such as the industrial Internet of things, connect traditional machinery and tools with actuators and sensors, allowing them to collect, transmit and act on data related to the production process. Together, these components create a networked system designed to sense, make predictions about and interact with the physical world and to take decisions, supporting production in real time.

A. A possible new technological paradigm

12. Industry 4.0 is considered a new technological revolution based on digital technologies and connectivity, the integration of technologies and the interconnections between the physical, digital and biological spheres. A technological revolution has a more profound and broader impact than the introduction of an incremental or radical technology. It changes economies and societies, how people relate with each other and the environment and requires profound institutional changes. The literature on technological change and

[10] UNCTAD, 2021b, *World Investment Report 2021: Investing in Sustainable Recovery* (United Nations publication, Sales No. E.21.II.D.13, Geneva).

[11] See https://unctad.org/news/global-investment-flows-rebound-first-half-2021-recovery-highly-uneven.

innovation has identified five technological revolutions since the industrial revolution, each taking around 50 years to unfold (see table).

Technological–economic paradigms

Revolution	*Paradigm*
First through third:	
Industrial revolution (from 1771)	Factory production, mechanization, productivity, timekeeping and timesaving, local networks
Age of steam and railways (from 1829)	Economies of agglomeration, industrial cities and national markets, scale as progress, standardization of parts, energy when needed (steam)
Age of steel, electricity and heavy engineering (from 1875)	Large steel structures, economies of scale of plants and vertical integration, distribution of power for industry (electricity), science as a productive force, worldwide networks, universal standardization, cost accounting
Fourth: Age of oil, automobiles and mass production (from 1908)	Mass production and markets, economies of scale and horizontal integration, standardization of products, energy intensity, synthetic materials, functional specialization, suburbanization, global agreements
Fifth: Digital revolution (age of ICT; from 1971)	Information intensity and instant communications, knowledge as capital, digital platforms and social media, connectivity and mobility, electronic commerce and electronic government, segmentation of markets, economies of scope, flat organizations and network structures, global value chains
Sixth: Industry 4.0 (from the 2010s)	Automation, digital integration, niche markets, local production on demand, sustainability, smart production, decentralization of processes, increased vertical and horizontal integration, reconfiguration of production, self-correction

Source: UNCTAD, based on C Perez, 2002, *Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages*, Edward Elgar. Cheltenham, United Kingdom, and K Schwab, 2017, *The Fourth Industrial Revolution*, Penguin, London.

13. Under the framework followed by the World Economic Forum, the first three revolutions coincide with the industrial revolution, the fourth and fifth coincide with the second and third industrial revolutions and industry 4.0 is therefore the fourth industrial revolution.[12] The latter is said to have no historical precedent in terms of the speed of spread, the breadth of industries affected and the magnitude and depth of changes it brings.[13] Although the technologies and solutions under industry 4.0 may seem to be in the distant future for many, all will be affected by this wave sooner or later.

B. Development and use of industry 4.0 in manufacturing

14. A few countries and a relatively small number of firms lead the development of industry 4.0 technologies. China and the United States of America are dominant in the number of publications and patents, accounting for approximately 26–41 per cent of relevant publications and 45–63 per cent of patents worldwide.[14] Both countries are leaders in investment and capacity in industry 4.0 technologies and are home to the largest digital

[12] Schwab, 2017. See https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/.

[13] Ibid.

[14] Based on UNCTAD, 2021a.

platforms, accounting for 90 per cent of the market capitalization, as well as half the world's hyperscale data centres, the highest rates of adoption of fifth-generation networks (over 45 per cent), 94 per cent of all funding of artificial intelligence start-ups in the past five years and 70 per cent of the world's leading researchers in artificial intelligence.[15] However, it is not clear whether China and the United States will extend their advantages in digital platforms into industry 4.0 technologies in manufacturing. An essential technology in this regard is the Internet of things. Firms from Western Europe have made significant investments in this technology and, together with China and the United States, account for about three quarters of all spending related to the Internet of things.[16]

15. High-technology manufacturing and research and development capacity is another critical element in the diffusion of industry 4.0. In this regard, economies may be divided into four major categories, namely, frontrunners, followers, latecomers and laggards.[17] The frontrunners are the 10 economies with 100 or more global patent family applications in industry 4.0 technologies, together accounting for 91 per cent of all global patent families and almost 70 per cent of exports and 46 per cent of imports, and these are the economies that create, sell and buy products using such technologies.[18] The followers are economies engaged with such technologies but with a smaller share of patents and trade. Together, frontrunners and followers comprise 50 economies actively engaging with industry 4.0 technologies. Other countries have shown low or no levels of activity in patenting or trading such technologies. Moreover, even among the 50 frontrunner and follower economies, industry 4.0 technologies have been adopted in only a few sectors and only a few firms have implemented smart production. Among latecomers and laggards, manufacturing firms mainly use analog technologies and are still in the process of adopting digital technologies.[19]

C. Benefits of industry 4.0 in manufacturing

16. The application of industry 4.0 technologies in manufacturing may result in productivity, energy efficiency and sustainability gains. In terms of productivity, firm-level surveys in Ghana, Thailand and Viet Nam show that firms that adopt advanced digital production technologies become more productive.[20] Such technologies increase the visibility of every step of production, highlighting areas for optimization. For example, one case study in Mexico of a power tool manufacturing plant showed that the use of Wi-Fi radiofrequency identification tags attached to nearly every material in a real-time location system allowed floor managers to slow down or speed up processes and determine how quickly employees completed tasks, resulting in greater labour efficiency by 10 per cent and increases in critical labour resource utilization rates by 80–90 per cent.[21]

17. Smart production also increases productivity by reducing downtime and maintenance costs. Estimates suggest that asset availability may potentially be increased by 5–15 per cent.[22] For example, in Portugal, a vehicle plant that installed vibration and temperature sensors on a machine with a long history of malfunctions was able, through use

[15] UNCTAD, 2021c, *Digital Economy Report 2021: Cross-Border Data Flows and Development – For Whom the Data Flow* (United Nations publication, Sales No. E.21.II.D.18, Geneva).

[16] Ibid.

[17] United Nations Industrial Development Organization, 2020, *Industrial Development Report 2020: Industrializing in the Digital Age*, Vienna.

[18] China; France; Germany; Japan; Netherlands; Republic of Korea; Switzerland; United Kingdom; United States; Taiwan Province of China.

[19] United Nations Industrial Development Organization, 2020.

[20] Ibid.

[21] See https://enterpriseiotinsights.com/20180102/smart-factory/three-smart-manufacturing-case-studies-tag23-tag99.

[22] See https://www.mckinsey.com/business-functions/operations/our-insights/digitally-enabled-reliability-beyond-predictive-maintenance.

of the Internet of things, to identify non-conformities early on, allowing for planned replacements and a return of approximately 200 per cent on the initial investment.[23]

18. Industry 4.0 technologies also positively affect the productivity of an economy. Economies actively engaging with such technologies show a faster growth in manufacturing value added than other countries. [24] Importantly, such increases in productivity are associated with increases in employment.

19. The digitalization of manufacturing processes can also offer opportunities for energy savings through the optimization or replacement of technologies that demand greater energy and the introduction of energy optimization functionalities and adaptations in business processes. Integrating real-time data capabilities in existing tools and systems can result in operational improvements and cost savings for manufacturers. For example, in a case study of a multinational company providing equipment and services to the plastics industry, the use of industry 4.0 technologies reduced power consumption in one plant by around 40 per cent; the company used submeters, that is, sensors measuring the flow of energy, for specific measurements of energy usage and pressure across several pieces of equipment and found that some equipment used power even when not in use, with machinery operating at higher levels of power than needed for optimal performance, and the ensuing changes in production parameters saved the equivalent of over $200,000 per year in energy costs.[25]

20. In smart factories employing the Internet of things and robots, improvements in algorithms could result in the continuous optimization of and increases in energy efficiency. For example, at a smartphone manufacturer based in China, changes in algorithms to optimize the operation of robots resulted in an increase in productivity by 50 per cent, without requiring new robots or machines to be purchased.[26]

21. Reducing waste also improves the sustainability of production. The savings gained from using three-dimensional printing instead of traditional production methods can be substantial in production processes and with regard to the weight and energy consumption of products using parts produced through such printing. For example, additive manufacturing in the production of less flight-critical lightweight parts for aircraft, such as brackets, hinges, seat buckles and furnishings, could result in a reduction of over 50 per cent in the weight of such parts, reducing aircraft mass by 4–7 per cent and fuel consumption by as much as 6.4 per cent.[27]

III. Industry 4.0 and inequalities

22. Given the benefits of industry 4.0 and considering the disparities in development and diffusion, how might it impact socioeconomic inequalities? The impact of industry 4.0 on inequalities can be considered with regard to the economic channels through which technology affects inequalities (profits, wages and jobs); and the framework of long waves of technological revolutions.

A. Effects on inequalities in profits, wages and jobs

23. Technological change and innovation affect inequality in terms of profits, wages and jobs, in a long chain reaction throughout the structure of an economy. With regard to

[23] J Fernandes, J Reis, N Melão, L Teixeira and M Amorim, 2021, The role of industry 4.0 and BPMN[business process model and notation] in the arise of condition-based and predictive maintenance: A case study in the automotive industry, *Applied Sciences*, 11(8):3438.

[24] United Nations Industrial Development Organization, 2020.

[25] See https://www.efficiencyvermont.com/blog/your-story/how-did-simple-efficiency-solutions-help-husky-save.

[26] See https://www.automate.org/case-studies/the-paradox-of-smart-manufacturing.

[27] R Huang, M Riddle, D Graziano, J Warren, S Das, S Nimbalkar, J Cresko and E Masanet, 2016, Energy and emissions saving potential of additive manufacturing: The case of lightweight aircraft components, *Journal of Cleaner Production*, 135:1559–1570.

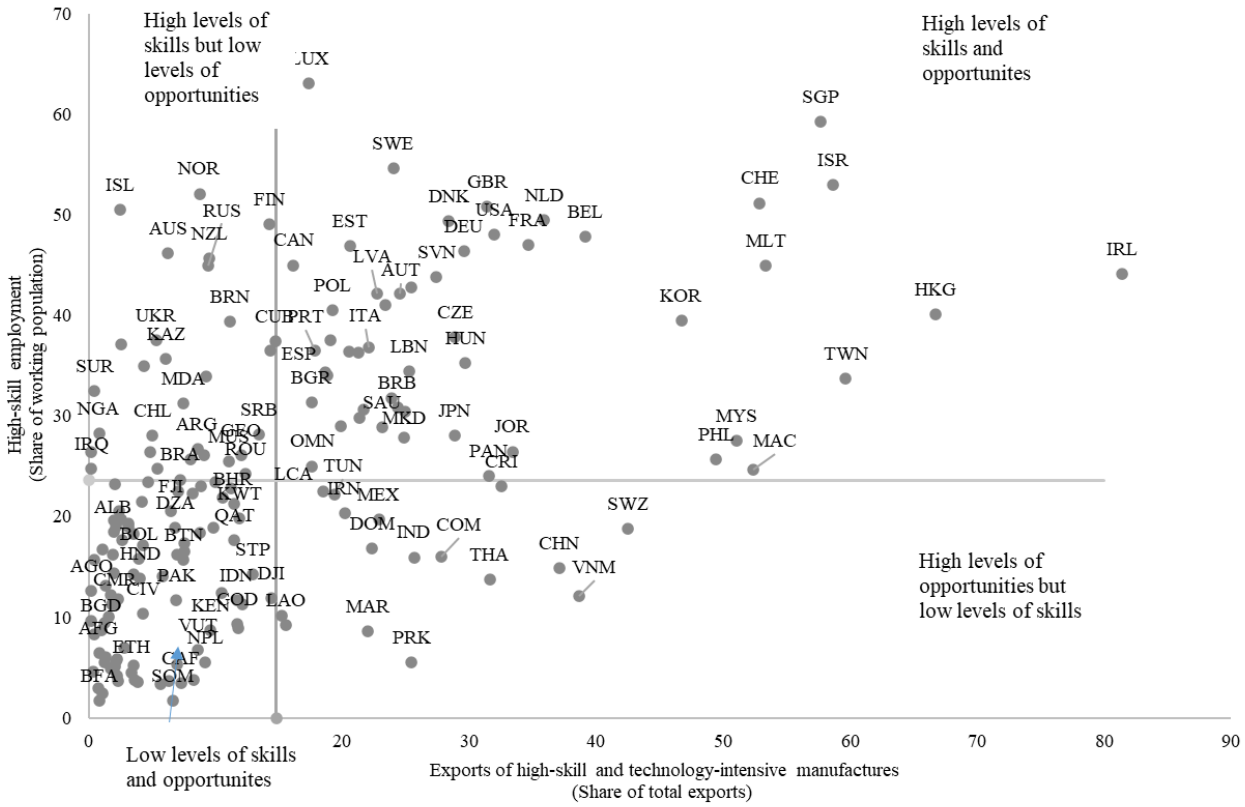
industry 4.0 in manufacturing, new technologies are used mainly in process innovation to increase productivity. Manufacturing firms deploying industry 4.0 technologies and introducing new products can earn greater profits than other firms in the same sector. The introduction of artificial intelligence and robots in smart production can also complement the jobs of skilled workers and increase demand for labour in non-routine tasks relative to routine tasks. Therefore, the initial direct impact of industry 4.0 is on inequality related to firm productivity within sectors and disparity in wages due to changes in occupations and tasks.

24. At the global level, countries with more manufacturing sectors in which firms adopt industry 4.0 technologies could expect to experience greater increases in productivity than other countries. At the same time, skilled workers may be better prepared to transition to smart production and less negatively affected by changes in occupations and tasks. The performances of economies in exports of high-skill and technology-intensive manufactures and in high-skill employment indicate the economies that may initially be better positioned to benefit from the diffusion of industry 4.0 technologies (figure 3).

Figure 3

Determining which economies may initially be better positioned to benefit from industry 4.0: Indicators of readiness

(Percentage)



Source: UNCTAD calculations, based on data from the UNCTADstat and the International Labour Organization databases.

Notes: The solid lines represent the global averages under these two indicators. Data labels use International Organization for Standardization economy codes.

25. One group of economies, including the United States and many economies in East Asia, Europe and South-East Asia, comprises economies with high levels of opportunity for the diffusion of industry 4.0 technologies, due to their specialization in high-skill and technology-intensive manufacturing, and with large shares of high-skill employment. Eight economies in this group show above-average performance levels and may benefit the most

from industry 4.0 in manufacturing relative to their populations and exports.[28] A second group of economies, including, for example, China, India, Mexico, Thailand and Viet Nam, comprises economies with high levels of opportunity given their share of high-technology exports, but shares of high-skill employment that are below the global average, indicating that the lack of skills may be an obstacle in broadly diffusing industry 4.0 technologies in manufacturing. A third group of economies, including, for example, developing countries with a greater reliance on commodities in the economic structure, such as Argentina, Brazil, Chile, Kazakhstan and Nigeria, comprises economies with shares of high-skill employment that are above the global average, indicating the potential for workers to adapt to industry 4.0 in manufacturing, but low levels of opportunity in terms of firms in high-technology sectors, and these economies may find it difficult to broaden the use of industry 4.0 technologies in manufacturing beyond the pockets of high-skill and technology-intensive manufacturing sectors. A fourth group of economies, including most developing countries, comprises economies with shares under both indicators that are below global averages; they do not have many high-technology sectors in the economic structure nor many high-skill jobs, and the diffusion of industry 4.0 technologies could therefore be slower. The analysis thus suggests that the initial diffusion of industry 4.0 technologies is more likely to increase inequalities between countries.

B. Effects on inequalities through technological revolutions

26. Technological revolutions affect inequalities. Such revolutions can be divided into two phases. The first entails the installation of the new technological paradigm, starting in a few sectors and places at the centre of the technological wave, such as the technology sector in the United States during the installation phase of the age of ICT, and entails, potentially, increasing income inequality due to the increasing wages of workers in the core industries of the new paradigm, including finance. The second phase entails the deployment of the technological paradigm and, historically, has involved more equitable participation in the growth of the economy. However, the end of this phase could be a time of social discontent following the realization that the social progress promised through the use of new technologies has left many people behind, as well as a period of merging and concentrating power in a few firms, giving rise to fortunes in the hands of a few.[29]

27. If this framework is applied to the present, the impact of industry 4.0 on inequalities depends on whether the current situation is the beginning of a new technological–economic paradigm or a continuation of the age of ICT.

28. In the first scenario, countries at the technological frontier are at the end of the deployment phase of the age of ICT and the start of the installation phase of the age of industry 4.0. This could be a period of discontent with the unequal outcomes and unrealized promises of widespread progress through the use of ICTs, as well as with the significant concentration of wealth among the owners of the major digital platforms. At the same time, there are concerns about the possible impact on inequality caused by new technologies. Such effects have not yet materialized given that the new paradigm is in the early stage, yet some have foreseen the ways in which it could increase disparities through impacts on production and consumption. Among developing countries, historically, the installation phase of a new technological paradigm has provided opportunities for some countries to catch up and others to forge ahead. In the installation phase of the age of ICT, some countries in Asia were able to catch up technologically and economically by developing capabilities to enter the ICT sector in both hardware and software, resulting in structural change towards technology-intensive export sectors. Similarly, the installation phase of industry 4.0 could take place when countries entering sectors associated with the new paradigm experience greater growth and catch up to the technological frontier. An increase in within-country inequality in countries at the technological frontier may be seen in the next couple of decades. At the same time, some developing countries may catch up and

[28] Ireland; Israel; Malta; Republic of Korea; Singapore; Switzerland; Hong Kong, China; Taiwan Province of China.

[29] Perez, 2002.

others may forge ahead, reducing inequality across countries. However, most developing countries would still need to catch up with the previous technological paradigms before progressing to industry 4.0.

29. In the second scenario, a period of increasing prosperity in developed countries could take place, with the increase in productivity currently experienced in the technology sectors taking place in other, traditional sectors of the economy through the diffusion of industry 4.0 technologies. However, this could also be a period of consolidation of the technological gap between countries at the technological frontier and others. Historically, catch-up trajectories tend to occur in the installation, not deployment, phase of a paradigm. In this scenario, therefore, there may be lower levels of inequality within developed countries, but a persistent gap across countries.

30. Both scenarios offer a dismal prospect for most developing countries unless effective action, supported by the international community, is taken to promote and support further economic diversification towards more technologically intensive industries and, at the same time, attempts to enter the sectors associated with the new paradigm.

IV. Specific challenges

A. Addressing the displacement of workers

31. Many studies predict a large share of jobs lost due to industry 4.0 technologies and the risk is particularly acute in developing countries, which tend to have more routine-type jobs. However, countries have different factor endowments, comparative advantages and sector compositions and, combined with uncertainty as to which sectors are prone to job displacement (manufacturing could be prone to automation through the use of robotics but services could be prone to automation through the use of artificial intelligence and other technologies), overall effects might not be as straightforward as the estimates suggest. Moreover, most alarmist scenarios do not consider that not all tasks are automated and, importantly, new products, tasks, professions and economic activities are created throughout an economy.

B. Addressing the reshoring of production and restructuring of foreign direct investment and global value chains

32. With the emergence of industry 4.0 technologies, labour-intensive work in developing countries could be replaced by technologies such as robotics and artificial intelligence in developed countries, reducing the comparative advantage in manufacturing of the former within global value chains and leading to the reshoring of production from developing to developed countries. Industry 4.0 technologies could increase the comparative advantage of developed countries in skill-intensive and capital-intensive industries, including intangible components that have become prevalent due to digital technologies. Combined, these effects could lead to the loss of developing countries' share of value addition within global value chains. On the other hand, decisions on foreign direct investment are based on not only labour costs but also other factors such as market access, favourable policy environments and incentives. Whether reshoring would occur also depends on implementation factors, such as switching costs, inertia and the coordination complexity associated with reshoring. Digital technologies could also encourage the participation of more firms in global value chains by bridging distances and reducing costs related to trade and assembly. Evidence from 2,500 firms from eight countries in Europe shows that reshoring is not common; only 5.9 per cent of the firms surveyed had reshored and 16.9 per cent had offshored, and the main reason for reshoring from emerging economies was flexibility in logistics rather than labour costs.[30]

[30] Austria; Croatia; Germany; Netherlands; Serbia; Slovenia; Spain; Switzerland (see United Nations Industrial Development Organization, 2020).

C. Protecting workers

33. Industry 4.0 relies on large amounts of data collected using sensors, wearable devices, global positioning systems, logs of worker performance and behaviour and the ratings and evaluations provided by users, combined with analyses conducted through the use of algorithms and artificial intelligence. The use of such data has the potential to improve productivity, yet there are several concerns, as follows: surveillance and monitoring practices can lead to intrusions into worker privacy; algorithms may be developed based on a narrow vision of productivity and efficiency without consideration of the hidden costs associated with tasks, resulting in a failure to capture the actual performance of the workforce; and algorithms and artificial intelligence may be biased, reflect cultural or gender biases and other prejudices and preferences and contain errors, with little transparency. Given such concerns, collective agreements have been implemented in various countries to regulate the use of technology in monitoring workers and directing work, aimed at preserving human dignity and the health and safety of workers; such efforts are still at an early stage.[31]

D. Addressing gender implications

34. Industry 4.0 could bring about important changes related to power, knowledge and wealth and may impact the pursuit of gender equality. Artificial intelligence is at the forefront of industry 4.0 and it is therefore critical to consider gender-related trends in the sector. Artificial intelligence systems tend to reflect and amplify existing biases and prejudices, especially with regard to gender, because women are underrepresented in this sector; women account for only 26 per cent of data and artificial intelligence-related positions in the workforce.[32] The effects of new technologies need to be better understood, particularly artificial intelligence, as they could affect gender equality by impacting women's employment, labour force participation and access to financial resources, thereby affecting women's economic and livelihood opportunities. Such an understanding can help in being able to address how industry 4.0 could be used to narrow the gender gap.

V. Harnessing industry 4.0 for inclusive and sustainable development

35. Several developing countries have undertaken the digitalization of industry and begun the partial adoption of industry 4.0 technologies. However, Governments face various challenges related to infrastructure, support institutions, appropriately skilled labour and the general preparedness of key industries. Strategic responses to the deployment of industry 4.0 technologies are highly contextual, reflecting national priorities and capacities for resource mobilization and levels of industrialization, digital infrastructure and technological and productive capabilities, as follows:[33]

(a) Developed countries with advanced manufacturing bases are already at the frontier of technological adoption and have focused policy responses on sustaining and regaining manufacturing leadership;

(b) Emerging developing countries have sought to narrow the technological gap, increase competitiveness and expand participation in higher value added parts of global value chains; policy responses have focused on fostering innovation and technological adoption in manufacturing and some of these countries have firms at the technological frontier deploying, or ready to deploy, industry 4.0 technologies, and a challenge is to facilitate deployment in traditional manufacturing sectors of the economy;

[31] See V De Stefano and A Aloisi, 2018, *European Legal Framework for Digital Labour Platforms*, European Union, Luxembourg.

[32] World Economic Forum, 2020, *The Global Gender Gap Report 2020*, Geneva.

[33] See United Nations Industrial Development Organization, 2020.

(c) Less technologically advanced and less diversified developing countries have fewer sectors exposed to the deployment of industry 4.0 technologies and lower levels of technological and innovation capacities in general; they should focus on diversifying economies, increasing the share of manufacturing in total output and establishing the required conditions for building digital infrastructure and skills to prepare for the deployment of industry 4.0 technologies.

36. Critical policy areas that stakeholders in developing countries, regardless of technological level, should consider in facilitating the deployment of industry 4.0 technologies in manufacturing, to reduce technological and income inequalities between countries and ensure that industry 4.0 contributes to reducing inequalities within countries, are addressed in this chapter.

A.Creating preconditions for harnessing industry 4.0

37. Developing countries will not be able to broadly harness industry 4.0 for development if they have weak industry (manufacturing) and digital infrastructure and low levels of skills. In the absence of these elements, few firms in developing countries will be able to use industry 4.0 technologies and even fewer will be able to adopt the use of smart production. Developing countries should also create the framework conditions required to deploy industry 4.0 technologies in manufacturing, including developing national strategies directing coordinated development and deployment; creating a multi-stakeholder mechanism institutionalizing a participatory approach to fostering industry 4.0; and building international cooperation to accelerate the transfer of technology and know-how.

(a) Diversifying the economy and building a manufacturing sector

38. To successfully facilitate the broad diffusion of industry 4.0 technologies and harness the benefits, developing countries should diversify production bases by mastering existing technologies (automation machinery and equipment). The State plays a crucial role in facilitating the emergence of productive capacities in the industrial sector. Governments should facilitate the identification of potential sectors for diversification, promote key potential new sectors of national interest (for example by targeting job creation, food security, energy security, industrialization and digital transformation), strengthen the effectiveness of innovation systems to support diversification, build coherence between science, technology and innovation policy and other economic policies (such as industrial, fiscal, trade-related and educational policies) and involve a wide range of actors. Concerns about the impact of production on the environment and related to the risks of climate change should be at the centre of such strategies and programmes, promoting diversification and technological upgrading towards greener manufacturing and a circular economy.

(b) Developing a digital infrastructure

39. The quality of digital infrastructure directly affects the ability of firms in developing countries to deploy industry 4.0 technologies. Governments in developing countries should promote affordable, high-quality access to the Internet. Key policy aspects include the mobilization of investment in ICT infrastructure and the creation of a regulatory environment for sound competition in the telecommunications sector. Governments should also try to bridge the connectivity gap between small and large firms.

(c) Building skills related to industry 4.0

40. Developing country Governments need to support businesses, including small and medium-sized enterprises, in building digital skills among the workforce to use ICTs efficiently in functions such as market research, product development, sourcing, production, sales and after-sales services. With technology increasing faster than skills, the risk of a skills mismatch is also increasing. Developing countries need to build and attract a skilled workforce while minimizing or reversing human capital flight comprising those with

disruptive skills. Policymakers should consider introducing incentives to retain qualified professionals or attract skilled expatriates.

(d) Developing national strategies for industry 4.0

41. A national strategy for industry 4.0 is critical in guiding innovation efforts towards developing and deploying industry 4.0 technologies in manufacturing. Such a strategy should identify the investment needed in physical infrastructure and human capacity, including training in the new digital skills required; key sectors requiring strengthened capacity; and aspects of the regulatory environment requiring changes in order for firms to adopt and adapt the technologies. Such a strategy could take many forms and could be a stand-alone national strategy or form part of national strategies for industrialization and manufacturing or science, technology and innovation. It is critical to align innovation and industrial policies, to harness industry 4.0 for manufacturing. A focus on increasing productivity growth requires various innovation and industrial policies, including collaborative projects.

(e) Fostering multi-stakeholder collaboration

42. Governments, business sectors, academia and other stakeholders should work together to drive the national deployment of industry 4.0 in a coordinated manner and aimed at national development goals such as structural transformation, economic diversification and job creation. Many countries could benefit from creating institutional spaces or mechanisms to bring together all relevant partners to develop a shared vision of industry 4.0 and coordinate the implementation of related technologies. The smooth functioning of a national innovation system often requires a good governance structure and the involvement of national and regional Governments and actors representing businesses, academia and research organizations. In countries with significant regional disparities, creating a multilevel governance structure can help distribute socioeconomic growth at the within-country regional level.

(f) Building international partnerships

43. Many developing countries can benefit from including an outward-looking dimension in national strategies for industry 4.0. Transnational knowledge, information exchanges and collaborations can offer invaluable opportunities to build new, and participate in existing, regional and continental value chains. For example, the African Continental Free Trade Area can foster the adoption of frontier technologies in critical areas such as transportation and logistics, financial technology, potable water and sanitation, smart cities, affordable housing and low-cost, high-quality health care.

B. Fostering the adoption of industry 4.0

(a) Raising awareness among businesses

44. Developing countries need to raise awareness of industry 4.0 and the positive impacts of related technologies. Governments should consider incentivizing businesses, especially small and medium-sized enterprises, to recognize the importance of digital adoption and start the process of digital transformation. To help raise awareness, Governments can set up meetings and activities to promote the benefits of industry 4.0. Governments can also help by promoting industrial transformation with relevant stakeholders in each sector and could arrange for demonstration initiatives in science parks, incubators, accelerators and innovation laboratories. As part of such initiatives, Governments should encourage academia, research organizations and civil society to work closely with the private sector to deploy new technologies.

(b) Investing in industry 4.0

45. Developing countries should consider formulating an industry 4.0 investment promotion plan to ensure that investment promotion and facilitation are in line with the national strategy for industry 4.0. There are several examples in this regard among

Commission members, as follows: the Government of Brazil has established the basket 4.0 initiative, which identifies priority industrial and technological segments of industry 4.0 for national investment and promotion; Latvia has designed and implemented the green channel initiative, eliminating administrative burdens on high value added investment; the Philippines has implemented an innovation-led industrial strategy aimed at removing obstacles to growth, to attract investment; South Africa, under the programme Digital Advantage 2035, guides the implementation of the national ICT research, development and innovation strategy and seeks to ensure comprehensive and transparent investment monitoring; and the Government of Thailand, as part of Industry 4.0 Strategy 2017–2036, aims to attract investment in future industries and services.[34]

(c) Financing the deployment of industry 4.0

46. Better access to finance could accelerate the use, adoption and adaption of industry 4.0 technologies. A challenge in this regard is that many areas associated with industry 4.0 are new to firms and financial intermediaries and those seeking and providing finance may express caution. For example, there are difficulties in proving business cases and returns on investment and ensuring that the new emerging applications of such technologies perform according to expectations. In this regard, innovation and technology funds financed by the public sector, international donors or development banks could become important instruments for innovation in developing countries, as they may be introduced relatively quickly and are flexible in design and operation.

C. Protecting workers and easing workforce transitions

47. Policymakers in developing countries should be attuned to changes in trade patterns and rapid technological changes in global value chains and how these could affect the workforce. Workers who cannot be trained or retrained and who may lose their jobs should be able to rely on stronger social protection mechanisms. There is a renewed importance placed on labour unions, to defend worker rights and legitimate concerns about jobs, given the increasing automation of tasks. Labour unions should strengthen and update collective bargaining agreements to cover the impact of industry 4.0 and devise new strategies for addressing the potential adverse effects of smart production on the well-being of workers. Trade unions could also try to include isolated workers, such as many workers in the gig economy. At the same time, employer organizations could develop targeted education and training to prepare workers for labour market changes and needs.

VI. International collaboration

A. Sharing knowledge and information and conducting research

48. International cooperation helps raise awareness among developing countries of industry 4.0 and the impacts through the sharing of knowledge and information. In this regard, the Commission on Science and Technology for Development is a forum for strategic planning and the sharing of lessons learned and best practices, drawing attention to new and emerging technologies. The World Summit on the Information Society Forum serves as a platform for sharing national strategies, policies, laws, programmes and initiatives concerning industry 4.0. The Global Manufacturing and Industrialization Summit, a joint initiative of the United Nations Industrial Development Organization and the Government of the United Arab Emirates, convened advanced technology actors to pursue the achievement of an inclusive and sustainable fourth industrial revolution. The United Nations Industrial Development Organization also provides for a multi-stakeholder

[34] See https://unctad.org/system/files/non-official-document/CSTD2021-22_c02_I_Brazil_en.pdf; https://unctad.org/system/files/non-official-document/CSTD2021-22_c06_I_Latvia_en.pdf; https://unctad.org/system/files/non-official-document/CSTD2021-22_c34_IU_Philippines_en.pdf; https://unctad.org/system/files/non-official-document/CSTD2021-22_c08_I_SouthAfrica_en.pdf; and https://unctad.org/system/files/non-official-document/CSTD2021-22_c36_IU_Thailand_en.pdf.

knowledge-sharing platform to create awareness of industry 4.0 and of opportunities and challenges in pursuing inclusive and sustainable industrial development.[35]

49. Several United Nations agencies are working on research, policy analysis and data collection concerning the potential economic and social impacts of industry 4.0 technologies and policy and regulatory responses. For example, the UNCTAD *Technology and Innovation Reports* have explored how to harness frontier technologies such as artificial intelligence and robotics for sustainable development and have critically examined the possibility that such technologies could widen existing inequalities and create new ones.

B. Helping design policies and strategies and implement initiatives

50. The international community has assisted Governments by providing policy advisory services concerning industry 4.0 and related technologies such as artificial intelligence. For example, the Economic and Social Commission for Western Asia has assisted member States in developing policies and strategies related to the fourth industrial revolution, such as the following: artificial intelligence and cloud computing policies, Jordan; artificial intelligence strategy, Lebanon; digital transformation strategy, Syria; and artificial intelligence policy and big data readiness assessment, State of Palestine. The UNCTAD programme of science, technology and innovation policy reviews assists countries in aligning science, technology and innovation policy with development strategies, providing information on how Governments can harness industry 4.0 technologies in traditional sectors and for economic diversification. The United Nations Industrial Development Organization supports policy development initiatives concerning industry 4.0, building awareness among policymakers and industry associations of new infrastructure, standards and policies to be developed or mainstreamed to benefit from industry 4.0.

C. Helping capacity-building

51. The development and deployment of industry 4.0 technologies require all actors in national innovation systems to build new capabilities and skills. International cooperation supports tailored programmes helping to support digitalization and upskilling and increase capacity to develop policies and strategies, for developing countries to benefit from the rapid progress of the digital technologies associated with industry 4.0. For example, the United Nations Industrial Development Organization supports small and medium-sized enterprises in Azerbaijan and Belarus in technological learning, smart manufacturing and innovation related to industry 4.0 and supports capacity-building in specific technologies in Kenya, such as strengthening capacity for operation and maintenance related to Internet of things technologies.[36]

D. Promoting technology transfer

52. The international community should pursue new innovative partnership approaches for promoting technology transfer related to industry 4.0, addressing market, innovation system and capability failures concerning the uptake of new technologies and business models. There is also a need to promote the transfer of innovation capabilities, that is, the ability to use a particular technology to generate value in the socioeconomic, material and natural context to which the technology is transferred. The international community should take practical actions and implement tailored solutions based on the local needs and absorption capacities of countries, leveraging solutions developed within a country whenever possible, for example through innovation hubs.

[35] See https://www.unido.org/unido-industry-40.

[36] See https://open.unido.org/projects/AZ/projects/190347; https://open.unido.org/projects/BY/projects/; and https://unctad.org/system/files/non-official-document/CSTD2021-22_c12_I_UNIDO_en.pdf.

E. Helping set legal frameworks, guidelines, norms and standards

53. Countries, individually and through concerted international efforts, need to guide the development and deployment of industry 4.0 to support sustainable development and leave no one behind. In this regard, the International Telecommunication Union is working to address the standardization requirements for Internet of things technologies and has established several focus groups on industry 4.0 technologies and their environmental impacts, including environmental efficiency requirements for artificial intelligence and other emerging technologies; and has published international standards related to industry 4.0 and associated technologies such as the Internet of things.

VII. Suggestions for consideration

54. Industry 4.0 in manufacturing entails smart production, that is, integrating and controlling production using sensors and equipment, including traditional machinery and robots, cobots and three-dimensional printers, connected to digital networks supported by artificial intelligence. The use of industry 4.0 technologies is expected to increase productivity and reduce the environmental impact of production. At the same time, most firms in developing countries are not yet utilizing such technologies. Developing countries need to further industrialize before they can broadly benefit from industry 4.0. They should implement a dual strategy of continuing to diversify their economies and foster competitive manufacturing while, at the same time, creating the conditions for the emergence and diffusion of industry 4.0 in their production bases.

55. Member States may wish to consider the following suggestions:

(a) Foster economic diversification and manufacturing competency;

(b) Facilitate an enabling digital infrastructure by mobilizing investment in digital infrastructure and creating a regulatory environment for sound competition;

(c) Develop national strategies for industry 4.0 to articulate a unified vision and deep understanding of the measures needed to harness industry 4.0 effectively;

(d) Foster multi-stakeholder collaboration to create an industry 4.0 ecosystem by creating institutional mechanisms bringing together all relevant partners to develop a shared vision of industry 4.0 and coordinate its implementation;

(e) Conduct foresight exercises to explore possible scenarios and develop a strategic vision and intelligence to shape the diffusion of industry 4.0;

(f) Build workforce skills for industry 4.0 through initiatives to qualify and retrain the workforce and pay particular attention to the different impacts of automation on women and men workers;

(g) Raise awareness among the private sector concerning the benefits of the deployment of industry 4.0 for competitiveness;

(h) Promote technological upgrading in manufacturing;

(i) Provide incentives for the private sector, including small and medium-sized enterprises, to use and develop applications using industry 4.0 technologies, including facilitating the acquisition of the hardware, software and tools needed.

56. The international community may wish to consider the following suggestions:

(a) Facilitate the exchange of research, knowledge, experiences, success stories and best practices with leading innovators, policymakers and regulators in developed and developing countries;

(b) Help design and implement national policies, strategies and programmes related to industry 4.0;

(c) Promote digital infrastructure development to allow for the deployment of industry 4.0 in manufacturing;

(d) Support developing countries in designing and implementing pilot programmes and initiatives to apply industry 4.0 technologies in priority sectors;

(e) Scale up capacity-building activities at the national and regional levels related to industry 4.0 technologies, including creating online and hybrid training programmes;

(f) Promote South–South, North–South and triangular cooperation on knowledge and technology transfer related to industry 4.0;

(g) Increase investment in education in science, technology, engineering and mathematics in developing countries through targeted programmes, for example by supporting the education of girls in these fields;

(h) Assist in benchmarking domestic industrial firms according to international firms that have achieved the transformation to industry 4.0;

(i) Strengthen international cooperation to develop ethical frameworks and guidelines for the adoption of industry 4.0 technologies.

57. The Commission is encouraged to take the following steps:

(a) Collect and share success stories and business cases demonstrating the impact of industry 4.0 technologies on inclusive and sustainable development;

(b) Facilitate international partnerships for mobilizing resources and providing technical assistance in effective policy mixes for incentivizing the adoption of industry 4.0 technologies at the firm level;

(c) Support the participation of actors in the innovation systems of member States in international networks and programmes to build their capacity in innovation with regard to industry 4.0.