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Issues Paper
on
Industry 4.0 for Inclusive Development

Unedited Draft

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I. Introduction

We live at the beginning of a new technological revolution around Industry 4.0 technologies such as artificial intelligence (AI), robotics, and the Internet of Things (IoT). The impact and response to the COVID-19 pandemic have accelerated the dissemination of these digital technologies. At its twenty-fourth session held in May 2021, the United Nations Commission on Science and Technology for Development (CSTD) selected "Industry 4.0 for inclusive development" as one of its two priority themes for the 2021–2022 inter-sessional period. This priority theme is directly relevant to SDG 9 on industry, innovation and infrastructure.

To contribute to a better understanding of this theme and to assist the Commission in its deliberations at its twenty-fifth session, the Commission secretariat has prepared this issues paper based on relevant literature and country case studies contributed by Commission members. The issues paper builds in particular on the analysis and empirical evidence of two recent publications of the United Nations. The first is UNCTAD's Technology and Innovation Report (2021a), which examined how the development and diffusion of frontier technologies affect (and are affected) by socio-economic inequalities. The second is UNIDO's Industrial Development Report (2020), which focused on the emergence and diffusion of advanced digital production (ADP) technologies of Industry 4.0 and their impact on the industrialization process in developing countries.

This issues paper focuses on Industry 4.0 as automation and data-driven changes in manufacturing technologies and processes and the trend towards smart factories, predictive maintenance, 3-D printing, smart sensors in production processes, and software to monitor, control and surveil workers. This process affects the differences in the relative productivity of firms of different sectors and economies. Thus, it impacts the prospects for industrialization and structural transformation of developing countries, which are critical for inclusive development and reducing 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 the social context 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 issues paper focuses on Industry 4.0 in manufacturing sectors and its impact on inequalities within and between countries. It does not cover the application of technologies associated with Industry 4.0 (e.g. AI, IoT) in other economic sectors (agriculture, services, and other industry outside manufacturing) or final consumption goods and services. The latter perspective was covered by the previous priority theme of the Commission for the 2019-2020 inter-sessional period (i.e. Harnessing rapid technological change for inclusive and sustainable development)[2] and examined in depth in the UNCTAD's Technology and Innovation Report 2021 on "Catching technological waves: Innovation with equity."[3]

Questions addressed in this paper include: How can developing countries take advantage of the window of opportunity presented by Industry 4.0 for technological upgrading and economic catch-up? What can governments do to ensure that Industry 4.0 does not increase inequality? What is the role of international cooperation in facilitating this process?

The findings of this issues paper are that Industry 4.0 in manufacturing can increase productivity and reduce the environmental impact of industrialization; it may create more jobs than replace and may

[2] https://unctad.org/system/files/official-document/CSTD2019-2020_Issues01_RapidTechChange_en.pdf

[3] https://unctad.org/webflyer/technology-and-innovation-report-2021

not shift the manufacturing wage advantage from emerging to industrialized economies. At the same time, most firms in developing countries are way far from using Industry 4.0; most are still using analog technologies in their production processes. These countries need to industrialize first before they can broadly benefit from Industry 4.0. The risk is that the slow industrialization and dissemination of Industry 4.0 in the manufacturing sector in developing countries would further increase inequalities between countries, replicating the pattern seen in previous technological revolutions. Therefore, developing countries cannot afford to miss this new wave of technological change. Much will depend on national policy responses. Each country will need science, technology and innovation policies appropriate to its stage 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.

The paper is structured as follows. Section II sets the stage by presenting the big picture of significant trends in global inequalities, industrialization in developing countries and the effects of the COVID-19 pandemic on these trends. Section III examines what constitutes Industry 4.0, including its long term impact as a technological paradigm and recent market trends. Section IV discusses how Industry 4.0 could impact inequalities through profits, wages and jobs, and the long-term effects of a technological revolution. Section V focuses on some of the key issues related to Industry 4.0 from the perspective of developing countries. Section VI covers what governments, the private sector and other stakeholders could do to harness Industry 4.0 for inclusive development. Section VII discusses areas for international collaboration. Section VIII presents conclusions and recommendations. The Issues paper also includes two Annexes. Annex A highlights the experience of some Commission's member countries with Industry 4.0 based on these country's contributions. Annex B lists questions for discussions to further the dialogue related to harnessing blockchain for inclusive and sustainable development.

II. Trends in industrialization, inequalities and the effects of COVID-19

As highlighted by the Technology and Innovation Report 2021, over the past 40 years, within-country inequality has increased in many regions, reaching in some cases alarming levels. This concerns not only developed countries such as the United States and several in Europe but also developing countries such as China and India.

In terms of inequality among countries, every wave of technological progress since the Industrial Revolution was associated with sharper inequality. Before 1800 there was very little income disparity across countries: inequality was a matter of domestic class divides. Today the average gap in per capita income between developed and developing countries is over $ 40,000 (UNCTAD, 2021a).

Inequality today is driven by the lottery of birthplace: a person born in a poor country suffers a 'citizen penalty' (Milanovic, 2016b). In upper-middle-income and high-income countries, the average share of the population living in extreme poverty is only 2 per cent, but in lower-middle-income countries, it is 14 per cent, and in low-income countries, 45 per cent (UNCTAD, 2021a). Similar disparities exist in child mortality rates and the prevalence of underweight children. Significant gaps also persist in education, particularly at higher levels: in 2018, in low-income countries, only 41 per cent of the population in the relevant age group were enrolled in secondary education – compared with 90 per cent in upper-middle and high-income countries (UNCTAD, 2021a). This gap is particularly important because inequality in education perpetuates income and other forms of inequality.

Progress has been faster for access to essential services such as clean water and electricity but slower for access to basic sanitation. In low- and lower-middle-income countries, only 63 per cent of the population have access to basic sanitation, compared with 86 per cent in upper-middle-income countries and universal access in high-income countries (UNCTAD, 2021a).

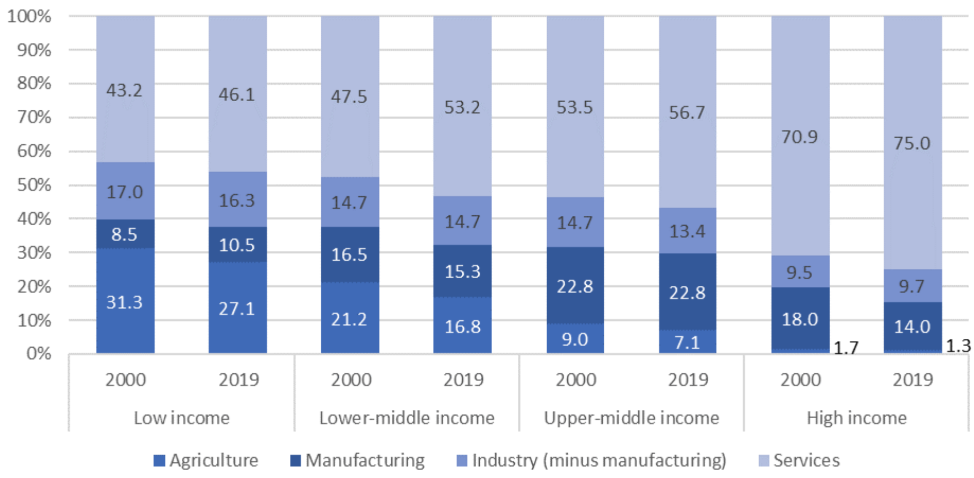
The low-income countries also tend to have wider internal inequalities. In 2018 in low-income countries, only 33 per cent of the rural population had access to electricity, compared with 70 per cent in urban areas. This gap was much narrower in lower-middle-income countries – rural 81 per cent and urban 96 per cent – and basically non-existent in upper-middle-income and high-income countries (UNCTAD, 2021a). Gender disparities are also more pronounced in low-income countries concerning mortality rates, vulnerable employment, and men and women's literacy rate.

Technology is not the only factor affecting between and within-country inequalities. Choices in trade, investment, monetary and fiscal policies, education are critical, but the impact of technological change is essential too.

Historically, successful development has been associated with industrialization, technological up-gradation, and structural transformation with shifts of output and employment away from low value-added activities, particularly subsistence agriculture, towards higher value-added sectors in industry and services. Within Industry, manufacturing offers better prospects for technological adoption and productivity growth, with spillover effects and potential for higher wages in the whole economy.

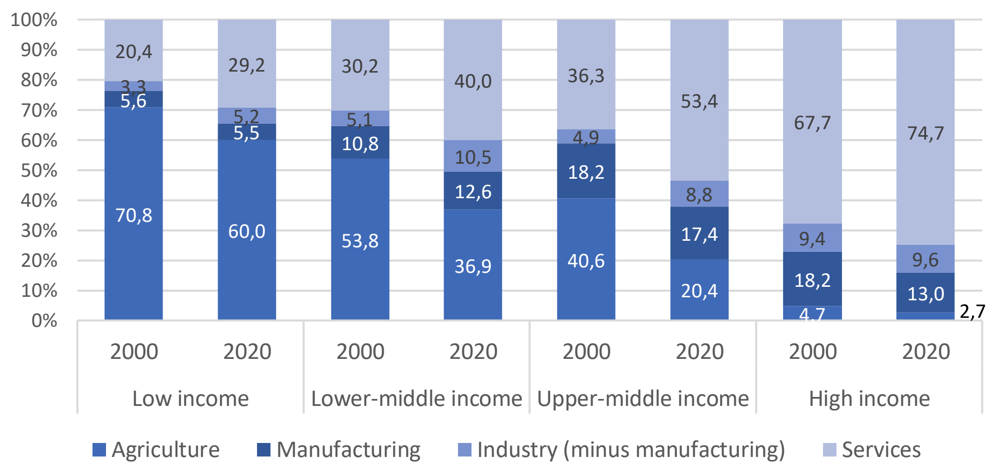
However, in the past two decades, on average, developing countries have followed a pattern of structural change characterized by a shift of value-added and employment mainly from agriculture to services, with a minor increase or even a reduction in the share of manufacturing value-added in total GDP (Figure II-1 and Figure II-2). This pattern shows the slow industrialization of low-income countries and early deindustrialization of lower-middle-income countries.

Figure II-1. Share of GDP by broad economic sector, income grouping (Percentage)



Source: UNCTAD based on data from UNCTAD Stat.

Figure II-2. Employment by broad economic sector, income grouping (Percentage)



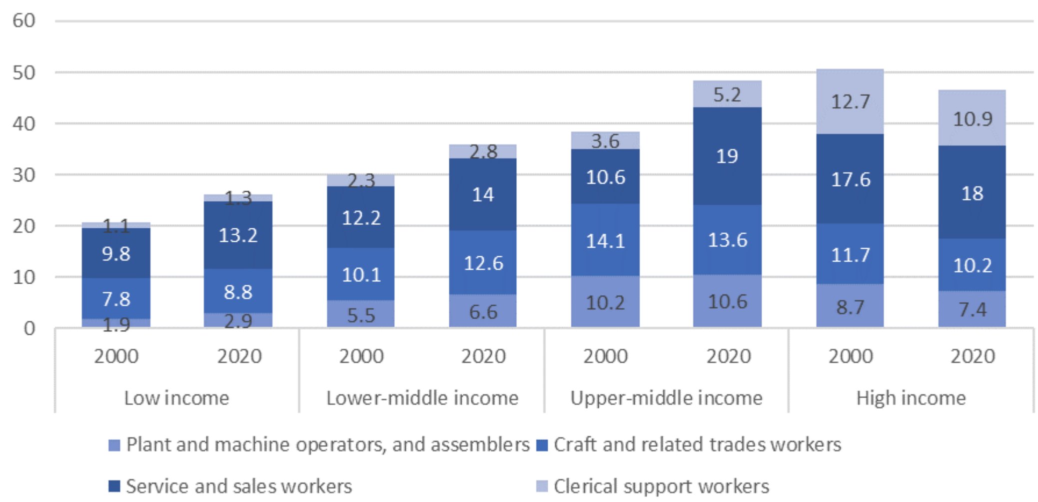
Source: UNCTAD, 2021a.

There are also several disparities between developed and developing countries in the global production of more sophisticated products. In developing countries, the average proportion of medium and high-tech value-added industry value added in total value-added was 40.8 per cent in 2016, compared with 48.9 per cent in developed countries. In the least developed countries, it was way lower, only 8.8 per cent and, most worryingly, this proportion was down from 16.5 per cent in 2000 (UNCTAD, 2021a).

The uneven and slow industrialization in developing countries has occurred despite the rapid expansion of foreign direct investment (FDI) and associated global value chains (GVCs) since the 1990s. GVCs account for some 80 per cent of international trade, and most developing countries are increasingly participating in GVCs; their share in global value-added trade increased from 20 per cent in 1990 to over 40 per cent in 2013 (UNCTAD, 2013). This increase was made possible due to policies (a wave of liberalization and export-led growth policies) and technological changes (e.g. declining costs of communications and trade) (UNCTAD, 2021d). Particularly, the rapid technological development has allowed the segmentation of production processes that led to the geographical diversification of production and the development of associated complex cross-border supply chains (UNCTAD, 2021). This expansion of production base often took the form of multinational enterprises (MNEs) from developed countries exploiting lower labour costs and market access in developing countries through FDI, hence shifting more labour-intensive work to developing countries. This expansion of FDI and GVCs became an important source of capital flow for developing countries, which turned to higher productivity and more diversified productive capacity. Also, from a development perspective, the inflow of FDI provided some opportunities for skill development, human capital growth and technology transfer in developing countries (ESCAP, 2021). Although there is a mixed experience of many developing countries in terms of technological learning through participation in GVCs, given that learning opportunities depend on the governance of the GVCs, the level of suppliers' competencies, and the maturity of the national innovation system (Pietrobelli and Rabellotti, 2011). Empirical evidence suggests that firms in developing countries tend to engage more in fabrication, a lower-skilled part of the GVCs, than firms from developed countries, which in their turn perform more R&D functions (higher-skilled) (Shin et al., 2012; Timmer et al., 2019).

Human capital is an important factor for technological learning and innovation, but it alone cannot account for the slow and uneven industrialization of developing countries because workers' skills in these countries have increased in the past two decades. From 2000 to 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, in contrast with the job polarization in developed countries (job polarization is the process in which there is a reduction in middle-skilled jobs compared with high and low-skilled jobs) (UNCTAD, 2021a). In the same period, the shares of high-skill workers have increased in all countries, most notably in middle-income countries, increasing about 6 percentage points. However, structural factors affect where skills are used. The bulk of the increase in middle-skill jobs has been in service and sales (Figure II-3Figure). The increase of middle-skill jobs associated with manufacturing (e.g. plant and machine operators, assemblers and craft workers) has been less pronounced.

Figure II-3. Employment in middle-skill jobs by type of activity (Percentage of total civil employment)



Source: UNCTAD based on data from ILOStat.

Given the persisting differences in economic structures of developing and developed countries, despite the worldwide increase in labour productivity in the past 30 years, the productivity gap between these countries only increased. The difference in output per worker between low and high-income countries grew from about $60,000 in 1991 to almost $90,000 in 2019 (UNCTAD, 2021a). [4] Many developing economies are still predominantly agricultural and resources-based, and there are significant gaps in productivity between traditional and modern sectors of these economies (McMillan et al., 2014). There is also a large share of the economy that is informal in most developing countries - both a symptom and a factor of lower productivity (La Porta and Shleifer, 2014). Globally, around 2 billion workers (60 per cent of the total labour force) were in informal employment in 2019, and 93 per cent of the world's informal work is in developing countries (ILO, 2018, 2021).

The COVID-19 pandemic is expected to increase job informality and insecurity. According to ILO (2021) estimates, the pandemic resulted in fewer jobs, longer job gaps and reduced work hours, equivalent to a loss of 100 million full-time jobs in 2021 and 26 million in 2022. The impact on the manufacturing sector depends on the production and trade structure of countries. For example, COVID-19 could result in 8.4 million people becoming unemployed in Thailand, 1.5 million of them in the manufacturing sector, particularly in malts and malt beverages and automotive industries (UNIDO, 2021a). In Bangladesh, workers in micro firms and SMEs in the textile, apparel and leather sectors were hit harder by layoffs (UNIDO, 2021b).[5] 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, hindering their deployment.

The pandemic also has hit international investment flows hard. In 2020, global FDI fell by 35 per cent (UNCTAD, 2021d). Developing economies were relatively resilient with a decline of 8 per cent, mainly because of robust flows in Asia. Still, the fall in FDI flows across developing regions was uneven, with 45 per cent in Latin America and the Caribbean and 16 per cent in Africa. Capital expenditure in manufacturing FDI projects was reduced globally by almost 90 per cent in June and July 2020 on a year-on-year basis (East and Kaspar, 2020). Recent estimates forecast a recovery in FDI in 2021, with an increase of 10 to 15 per cent (UNCTAD, 2021d). Prospects are uncertain, but it is expected that Asia continues to be resilient. At the same time, substantial recovery of FDI flows in Latin America and the Caribbean, and Africa is unlikely in the short term. This slow recovery may reduce the opportunities for these regions to benefit from FDI that uses Industry 4.0 technologies.

Private sector decisions regarding their participation in GVCs may also be affected by the experience of the COVID-19 crisis. UNCTAD (2021b) has identified four possible trajectories for GVCs as a result of the pandemic, depending on the industry's starting points.

- The first is reshoring leading to shorter, less fragmented value chains and a greater geographical concentration of value-added, primarily in higher technology-intensive sectors (e.g. automotive, machinery and equipment, and electronics). This trajectory could make access to and upgrading in global value chains more difficult for developing countries.
- The second is the diversification of economic activities primarily affecting services and global value chain-intensive manufacturing (e.g. textiles and apparel), increasing opportunities for new entrants with a high-quality hard and soft digital infrastructure.
- The third is regionalization, reducing the physical length of supply chains, benefiting developing regions with industries seeking investments in regional markets in sectors such as food and beverages and chemicals.

[4] Output per worker in $ constant international 2011 prices.

[5] To access the impact of COVID-19 on job in manufacturing, UNIDO is implementation of a series of online firm-level surveys. For more information, see https://www.unido.org/covid19_surveys.

- Fourth, replication and creation of shorter value chains and bundling of production stages with more geographically distributed activities and concentrated value-added. This is especially relevant for hub-and-spoke sectors such as pharmaceuticals and regional processing industries.

Out of these four potential trajectories, reshoring could hinder the deployment of Industry 4.0 in developing countries, given that it is more likely to affect high technology-intensive sectors that are also leading users of Industry 4.0 technologies.

Against this backdrop of persisting inequalities, slow industrialization trends in most developing countries and the impact of COVID-19 on employment, FDI and GVCs, what would be the effect of the emergence and dissemination of Industry 4.0 in manufacturing? Would it facilitate or hinder the industrialization of developing countries? Would it reduce or increase inequalities?

To help answer these questions, the next section examines the concept of Industry 4.0, how Industry 4.0 technologies are used in manufacturing, and what changes they bring to production.

III. Industry 4.0: concept and main characteristics

Industry 4.0, or often interchangeably called the Fourth Industrial Revolution, refers to the smart and connected production systems made possible by the new technologies, particularly with the increased use of automation and data exchange (UNIDO, 2017). While the technologies identified as part of Industry 4.0 vary by source, it is commonly understood that AI, IoT, big data, robotics and 3D printing are integral parts of this new wave (UNCTAD, 2019a, 2021a).

The particular case of using these Industry 4.0 technologies in manufacturing results in “smart” manufacturing production systems, also known as the smart factories or smart production. Smart production integrates and controls production using sensors and equipment connected to digital networks supported by artificial intelligence (UNIDO, 2020). Industry 4.0 in manufacturing entails new forms of interaction between humans and machines through a combination of traditional and new technologies in three main components— hardware, software and connectivity (Table III-1). The hardware components comprise both modern industrial robots (robots operating separately from workers), cobots (robots cooperating with workers in the execution of tasks), intelligent automated systems, 3D printers for additive manufacturing, as well as traditional and less technologically advanced machinery, equipment and tools.

Table III-1. Selected industry 4.0 technologies in manufacturing

Technology	Description	
Hardware components		
Industrial robots		Robots are programmable machines that carry out actions and interact with the environment via sensors and actuators either autonomously or semi-autonomously. Industrial robots usually work in place of and separated from workers, automating almost entirely the processes on the factory floor. Examples are spot welding robots used in the auto industry.
Cobots		Cobots are robots that work in collaboration with humans. They are easily re-programmable, for example, by a worker guiding the arm of the cobot through a new path. Several industries use cobots in various tasks such as machine tending (automated operation of industrial machine tools in a manufacturing plant), packaging and palletizing.
3D printing		3D printing (also known as additive manufacturing) produces three-dimensional objects based on digital information. 3D printing can create complex objects with fewer materials required. 3D printers are used for prototyping and also for final production in manufacturing.

Connectivity components		
Internet of Things (IoT)	The IoT refers to internet-enabled physical devices that collect, share and act based on data. The application fields of IoT are vast; typical fields include wearable devices, smart home, healthcare, smart city and industrial automation. In manufacturing, IoT connects traditional machinery and tools with actuators and sensors.	
Actuators		An actuator is a component of a machine that is responsible for moving and controlling a mechanism or system. It could be pneumatic, hydraulic, electric, thermal and magnetic. Actuators could, for example, measure heat or motion energy to determine the resulting action in the machine.
Sensors		Sensors are devices that detect external and internal conditions of equipment and products and send that information through the digital network. They can comprise temperature, humidity, pressure, proximity, level, gas, infrared, optical sensors, accelerometers, and gyroscopes.
Software components		
Big data	Big data is a term used for datasets whose size or type is beyond the ability of traditional databases to capture, manage and process. Big data enables decisions by tapping into data traditionally inaccessible or unusable.	
Artificial intelligence (AI)	AI is normally defined as the capability of a machine to engage in cognitive activities typically performed by the human brain. Although many perceive AI as a technology of the future, AI applications that focus on narrow tasks are widely available today, such as recommending what to buy online, spotting spam or detecting credit card fraud.	

Source: UNCTAD based on UNIDO (2020) and UNCTAD (UNCTAD, 2021a). Images: Industrial robot (https://fanuc.co.za/products/industrial-robots/); cobot (https://www.universal-robots.com/blog/how-cobots-are-levelling-the-manufacturing-playing-field/); 3D printring (https://www.amchronicle.com/news/felixprinters-unveils-two-new-large-format-3d-printers/); actuators (https://www.manufacturing.net/home/article/13194104/costs-and-capabilities-of-pneumatic-electric-actuators); sensors (https://www.mgsuperlabs.in/featured-brands/national-control-devices/sensors/environmental-sensor/7083/industrial-iot-wireless-predictive-maintenance-sensor).

These technologies, including robots, are not new to the production process in manufacturing; what makes smart production different is the other two components: software and connectivity. Connectivity is accomplished through digital networks and, more importantly, industrial IoT, by connecting traditional machinery and tools with actuators and sensors, allowing them to collect, transmit, and act on data related to the production process. The software component comprises more traditional ICT such as enterprise systems, computer-aided manufacturing (CAM), computer integrated manufacturing (CIM) and computer-aided design (CAD), as well as data analytics based on big data and AI. Together, these components create a smart networked system designed to sense, make predictions, interact with the physical world, and take decisions, supporting production in real-time (UNIDO, 2020).

For example, sensors (IoT equipment) could detect specific actions such as temperature change and send the data (big data) for analysis by artificial intelligence. Then, the analyzed data and following instructions could be communicated to optimize the downstream stages of the manufacturing process, such as robotics and 3D printers, thereby minimizing downtime or streamlining the production process (UNIDO, 2021c). Among the principles of Industry 4.0, the two key salient principles are:

a) Automation and decentralization of tasks, predictions and decisions – including automation by robotics and automation of analyses, predictions, decision-making processes and self-correction using big data and artificial intelligence without the need for human interference.
b) Interconnection and the ability of machines, sensors, devices and people to connect and exchange data and information – IoT allows people, devices, algorithms, AI and other components to communicate and interact, improving efficiency, productivity and problem-solving capabilities.

A. A new technological paradigm?

The idea of Industry 4.0, popularized through the work of the World Economic Forum, is that we are at the beginning of a new technological revolution based on digital technologies and connectivity, and also on the integration of technologies and the interconnection between physical, digital and biological spheres (Schwab, 2013). A technological revolution, also called a new techno-economic paradigm, has a more profound and broader impact than the introduction of an incremental or even 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 innovation has identified five technological revolutions since the Industrial Revolution, each taking around 50 years to unfold (Perez, 2002, 2010, 2015) (Table III-2). The first three basically coincide with the First Industrial Revolution as per the framework of the World Economic Forum, and the fourth and fifth coincide with the Second and Third Industrial Revolutions, respectively.

Table III-2. Techno-economic paradigms

Industrial revolution	Tech revolution	New tech or new and redefined industries	Techno-economic paradigm
First	The industrial revolution (From 1771)	Mechanized cotton industry, wrought iron, machinery	Factory production, mechanization, Productivity, time keeping and time-saving, local networks
	Age of steam and railways (From 1829)	Steam engine and machinery, iron and coal mining, railway construction, rolling stock production	Economies of agglomeration, industrial cities, national markets, scale as progress, standard parts, energy when needed (steam)
	Age of steel, electricity and heavy engineering (From 1875)	Cheap steel, steam engine for steel ships, heavy chemistry and civil engineering, electrical equipment industry, copper and cables, canned and	Giant structures (steel), economies of scale of plant, vertical integration, distribute power for industry (electricity), science as a productive force, worldwide networks and empires, universal standardization, cost accounting

		bottled food, paper and packaging	
Second	Age of oil, automobile and mass production (From 1908)	Mass-produced automobiles, cheap oil and oil fuels, petrochemicals (synthetics), internal combustion engine, home electrical appliances, refrigerated and frozen foods	Mass production and markets, economies of scale, horizontal integration, standardization of products, energy intensity, synthetic materials, functional specialization, suburbanization, world agreements
Third	Age of ICT (From 1971)	Cheap microelectronics ICTs, Internet and digital revolution, control instruments, biotech and new materials	Information intensity, instant communication, knowledge as capital, digital platforms, social media, connectivity, mobility, e-commerce, e-government, segmentation of markets, economies of scope, flat organizations, network structures, Global Value Chains
Fourth	Industry 4.0 *(speculative)*	AI, IoT, robots, drones, 3D printing, blockchain, Smart production, Smart cities, Renewable energy	Automation, digital integration, niche markets, local production on demand, sustainability; interconnection and the ability of machines, sensors, devices and people to connect and exchange data and information; decentralization of processes, increasing vertical and horizontal integration (blurring boundaries), the ability for reconfiguration of production and self-correction

Source: UNCTAD based on Perez (Perez, 2002) and (Schwab, 2013).

How is the Fourth Industrial Revolution different from previous ones? The First Industrial Revolution used water and steam power to mechanize production; the Second used electric power to create mass production; and the Third used electronics and information technology to automate production (World Economic Forum, 2016). Building on the Third, the Fourth Industrial Revolution is expected to exploit and combine hardware, software, and connectivity, as mentioned in the section above, to collect and analyze vast amounts of data with active interactions among technologies (UNIDO, 2021c).[6]

Unlike the Third Industrial Revolution that has reached many parts of the world, the Fourth Industrial Revolution is not yet in global reach. As with other technological revolutions, only a few countries lead this Industrial Revolution process, underpinned by dynamics such as economies of scale and network effects. While evidence regarding the actual dissemination of Industry 4.0 technologies on production in developing countries is still relatively limited, recent studies carried out in Viet Nam and Senegal suggest that a large share of firms in these countries are not using Industry 4.0 technologies yet (Cirera, Comin, Marcio, et al., 2021; Cirera, Comin, Cruz, et al., 2021). This pattern seems to be the case even

[6] Not all scholars view Industry 4.0 as a new tehcnological paradigm. For example, Carlota Perez is of the view that AI, robots, big data and other technologies associated with Industry 4.0, and the change they bring, are part of the Fifth technological paragdim that started in 1970s, not a new tehcnological paradigm (Perez, 2013, 2015).

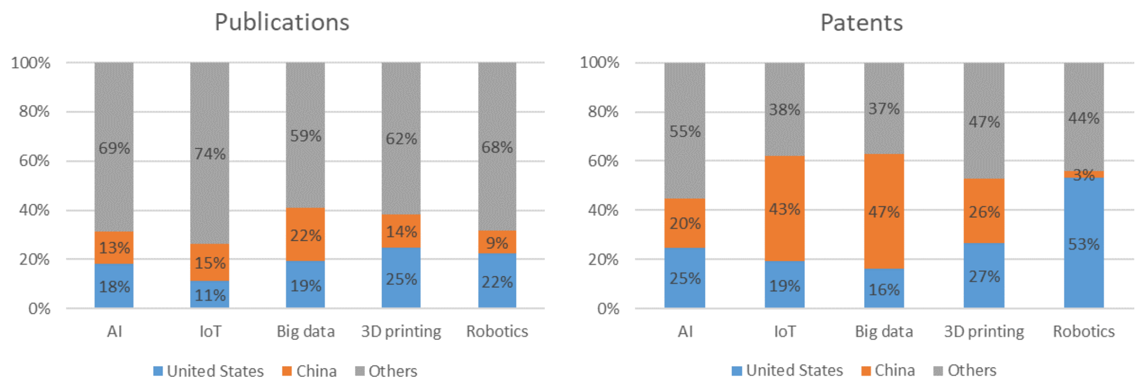
in high-middle-income developing countries. For example, while accounting for over 90 per cent of all enterprises in Brazil, most micro, small and medium enterprises (MSMEs) are still surrounded by the Second Industrial Revolution technologies.

While the technologies and the solutions offered by Industry 4.0 seems a distant future to many countries, it is expected that most parts of the world will be affected by this wave sooner or later, as the Fourth Industrial Revolution is said to have no historical precedent in terms of the speed of spreading, breadth of industries and societies that affect and the magnitude and depth of changes it brings (World Economic Forum, 2016). Therefore, it is critical for all countries to understand the implications of the Fourth Industrial Revolution in various dimensions.

B. Development and use of Industry 4.0 in manufacturing

The development of Industry 4.0 technologies has been led by a few countries and relatively a small number of firms. Publication (Figure III-1) and patent (**Error! Reference source not found.**) data on each Industry 4.0 technology show that the United States (in blue) and China (in orange) are dominant players in the market, together accounting for approximately 26 to 41 per cent of publications and 45 to 63 per cent of patents worldwide. Similarly, a list of major provider firms for each technology (Table III-3) indicates that American firms (in blue) are dominant players in the market, particularly those based on digital technologies (UNCTAD, 2021a).

Figure III-1. Country share of publications and patents by technology (percentage)



Source: UNCTAD, 2021a.

Table III-3. Major technology provider firms by technology

AI	*IoT*	*Big data*	*3D printing*	*Robotics*
Alphabet	Alphabet	Alphabet	3D Systems	ABB
Amazon	Amazon	Amazon Web Services	ExOne Company	FANUC
Apple	Cisco	Dell Technologies	HP	KUKA
IBM	IBM	HP Enterprise	Stratasys	Mitsubishi Electric
Microsoft	Microsoft	IBM		Yaskawa
	Oracle	Microsoft		Hanson Robotics
	PTC	Oracle		Pal Robotics
	Salesforce	SAP		Robotis
	SAP	Splunk		Softbank Robotics
		Teradata		Alphabet/Waymo
				Aptiv

Source: UNCTAD, 2021a.

Notes: American companies are shown in blue, Chinese companies in orange and others in grey.

One possible explanation for American companies' high penetration rate in AI, IoT, big data and blockchain is the prevalence of cloud computing platforms owned by American companies such as Amazon Web Services (AWS), Microsoft Azure and Google Cloud Platform (GCP). While the services covered by each platform may vary, these platforms generally offer a wide range of one-stop services related to AI, IoT, big data and beyond on a pay-as-you-go basis. The concentration on large platforms is likely to continue, as more users prefer their services than build their own systems from scratch, and competitors find it difficult to catch up due to network effects, the rising switching cost for users and economies of scale (UNCTAD, 2019b).

As highlighted in UNCTAD's Digital Economy Report 2021, both the United States and China stand out in investment and capacity in key Industry 4.0 technologies. They are home to the world's largest digital platforms – Apple, Microsoft, Amazon, Alphabet (Google), Facebook, Tencent and Alibaba – accounting for 90 per cent of the market capitalization. They also have half the world's hyperscale data centres, the highest rates of 5G adoption in the world (over 45 per cent), 94 per cent of all funding of AI start-ups in the past five years, and 70 per cent of the world's top AI researchers (UNCTAD, 2021c).

However, it is not clear if the United States and China will extend their advantages in digital platforms into Industry 4.0 in manufacturing. As discussed in the section above, an essential technology for Industry 4.0 in manufacturing is IoT. In that technology, firms from Western Europe have also made significant investments, and together with China, the United States, they account for about three-quarters of all IoT spending (UNCTAD, 2021c).

High-tech manufacturing and R&D capacity is another critical element for the diffusion of Industry 4.0. In this regard, UNIDO's Industrial Development Report 2020, based on the work of Foster-McGregor et al. (2019), presents the assessment of trade and patenting of technologies associated with Industry 4.0 for manufacturing. It divides countries into four major categories: frontrunners, followers, latecomers and laggards. The frontrunners are ten economies with 100 or more global patent family applications in Industry 4.0 technologies: China, France, Germany, Japan, the Netherlands, the Republic of Korea, Switzerland, Taiwan Province of China, the United Kingdom, and the United States. They together account for 91 per cent of all global patent families. These are the countries that are creating, selling and buying products using these technologies. Globally, they account for almost 70 per cent of exports and 46 per cent of imports. The followers are economies that engage with these technologies but with a smaller share of patents and trade. Yet, some of them have a higher percentage of global patents (e.g. Israel, Italy and Sweden) – these are followers innovators - or have high values of exports (e.g. Austria and Canada) – these are followers exporters. Others are followers importers, showing a high percentage of imports of Industry 4.0 technologies (e.g. Mexico, Thailand and Turkey). Together, frontrunners and followers comprise 50 economies that are actively engaging with Industry 4.0 technologies in one way or another. The rest of the world has shown low (latecomers) or very low to no activity (laggards) in patenting or trading these technologies.

Moreover, even within the 50 countries that are frontrunners or followers, only a few sectors have adopted Industry 4.0 technologies, and only a few firms have implemented smart production. In their turn, in latecomers and laggards, manufacturing firms use mainly analog technologies; they are still adopting digital technologies and still lack the full command of them (UNIDO, 2020).

C. Benefits of Industry 4.0 in manufacturing

The application of Industry 4.0 technologies in manufacturing is expected to result in productivity, energy efficiency, and sustainability gains.

In terms of productivity, the result of firm-level surveys in Ghana, Thailand and Viet Nam shows that firms that adopt advanced digital production technologies become more productive, even after controlling for a firm's age, investments in research and development and machinery, human capital and GVCs participation (UNIDO, 2020). At the firm level, Industry 4.0 can be a source of productivity increase through higher visibility of every step of production and the possibility of identifying areas for optimization. For example, in a case study, a power tool manufacturing plant in Mexico has used Wi-Fi radio-frequency identification tags attached to nearly every material in a real-time location system.[7] The system allows floor managers to slow down or speed up processes and see how quickly employees complete their respective tasks, which resulted in an estimated 10 per cent greater labour efficiency and 80 to 90 per cent increases in critical labour resources utilization rates.

Smart production also increases productivity through savings by reducing downtime and reducing maintenance costs. According to McKinsey (2020), firms that have adopted predictive maintenance have saved 20 to 30 per cent in maintenance costs. McKinsey consulting also estimates the potential for increasing production line availability by 5 to 15 per cent (Bradbury et al., 2018). For example, the analysis of a case study of Industry 4.0 in a plant of the carmaker Renault in Portugal, Alarcón et al. (2021) reported that the factory had installed vibration and temperature sensors on a machine with a long history of malfunctions, and through IoT, they identified early non-conformities that allowed planned replacement and intervention on the equipment that resulted in a return of approximately 200 per cent of the initial investment.

UNIDO's Industrial Development Report (2020) also notes that Industry 4.0 technologies positively affect the economy's productivity as a whole. Economies actively engaging with these technologies show faster manufacturing value added (MVA) growth than other countries. More importantly, this increase in productivity was associated with an increase in employment.

The digitization of manufacturing processes can also offer opportunities for energy saving through the optimization or replacement of higher-energy demand technologies, the introduction of energy optimization functionalities or adaptations in the business processes (UNIDO, 2017). For example, in a case study of a multinational company providing equipment and services to the plastics industry, Industry 4.0 technologies reduced the power consumption in one of its plants by around 40 per cent. The company first used submeters (sensors that measure the flow of energy) for precise measurements of energy usage and pressures across several pieces of equipment. It found that some equipment was using power even when not in use, and machinery was operating at higher power levels than needed for optimal performance. Using that information, changes in production parameters resulted in energy savings equivalent to over USD 200,000 a year.[8] This example shows how integrating real-time data capabilities to existing tools and systems can result in manufacturers' operational improvements and cost savings.

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

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

In the case of smart factories that already employ IoT and robots, improvements in the algorithms could result in continuous optimization and increases in energy efficiency. For example, in a case study of a smartphone manufacturer based in China that uses robots for tasks such as pick and place, inspection, and mechanical component testing, changes in the algorithm to optimize the operation of the robots resulted in an increase in productivity of these machines by 50 per cent, without buying any new robots or machines, and requiring the same levels of energy.[9]

The possibility of reducing waste in production processes also offers the opportunity to improve the sustainability of production. For example, the savings in using 3D printing instead of traditional production methods can be substantial in the production itself and the weight and energy consumption of products that use parts produced by 3D printing. A study on the potential of additive manufacturing on the production of less flight-critical lightweight aircraft parts, such as brackets, hinges, seat buckles, and furnishings, found that it could result in more than 50 per cent reduction in the weight of these parts (Huang et al., 2016). For example, 3-D printing a bracket reduced its weight from 1.09 kilograms to 0.38 kilograms. When considering the number of brackets in a plane, that could reduce its weight by 4 to 7 per cent, resulting in a reduction in airplane fuel consumption by as much as 6.4 per cent.

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

IV. Industry 4.0 and inequalities

Given these Industry 4.0 benefits listed in the previous section and considering the disparities in its development and diffusion, how would it impact socio-economic inequalities?

As mentioned in the Introduction, several factors affect inequalities, and technologies are only one of them. Nevertheless, we can consider the impact of Industry 4.0 on inequalities through two viewpoints: the first is the economic channels through which technology affects inequalities (profits, wages and jobs); the second is the framework of long waves of technological revolution. Each of these perspectives provides some pieces of information that can help us build a picture of how the development and diffusion of Industry 4.0 technologies in manufacturing could impact inequalities within and across countries.

A. Industry 4.0 affecting inequalities through profits, wages and jobs

At a higher level of analysis, new technologies can affect inequalities through the perspective of people as consumers and users of technologies as final products (e.g. using a smartphone to communicate with friends) or as a user of technologies in the production process (e.g. using a smartphone as a business tool) (UNCTAD, 2021a). In the case of Industry 4.0 in manufacturing and how it can impact inequalities, the relevant perspective of analysis is through the production lens.[10]

From the production perspective, technological change and innovation affect inequality through jobs, wages and profits, in a long chain reaction throughout the structure of the economy (Auerswald, 2010; Van Reenen, 2011; Acemoglu and Autor, 2011a; Vivarelli, 2014; Brynjolfsson and McAfee, 2016). Technological change creates, destroys and changes jobs, resulting in winners and losers in this process, and international trade transmits these effects across countries. It also impacts wages and profits, which affect inequalities between wage earners, between them and the owners of capital, and between the owners of capital.

Inequalities related to jobs, wages and profits are rather common and could arise in different points of the economic structure (e.g. occupations, firms, sectors) (Figure IV-1). The resulting income inequality between any two people is a composition of these various disparities. In a stylized fashion, inequalities first emerge between those who have a job (and thus have a labour income) and the unemployed. Among those who are employed, inequalities can further arise due to differences in wages. These disparities result from differences in skills at the same occupation (Juhn et al., 1993), in the occupations within a firm (Barth et al., 2016), between firms within a sector (Mueller et al., 2017), and between sectors within a country (Hartmann et al., 2017). At each of these levels, there is a hierarchy of competence and competition for the distribution of the rewards of production. For example, within an occupation, some skills are considered more productive (Keep et al., 2006) or in higher demand or less available (Juhn et al., 1993; Leuven et al., 2004) and can command a higher wage. In a firm, some occupations are considered more productive than others and are rewarded with higher wages. Some professions can also hold control over a productive or social bottleneck (e.g. some regulated professions) and hence deliver some form of rent (Bol and Weeden, 2015). Within a country, the more innovative and productive sectors and firms can claim higher profits and pay higher average wages (Guadalupe, 2007).

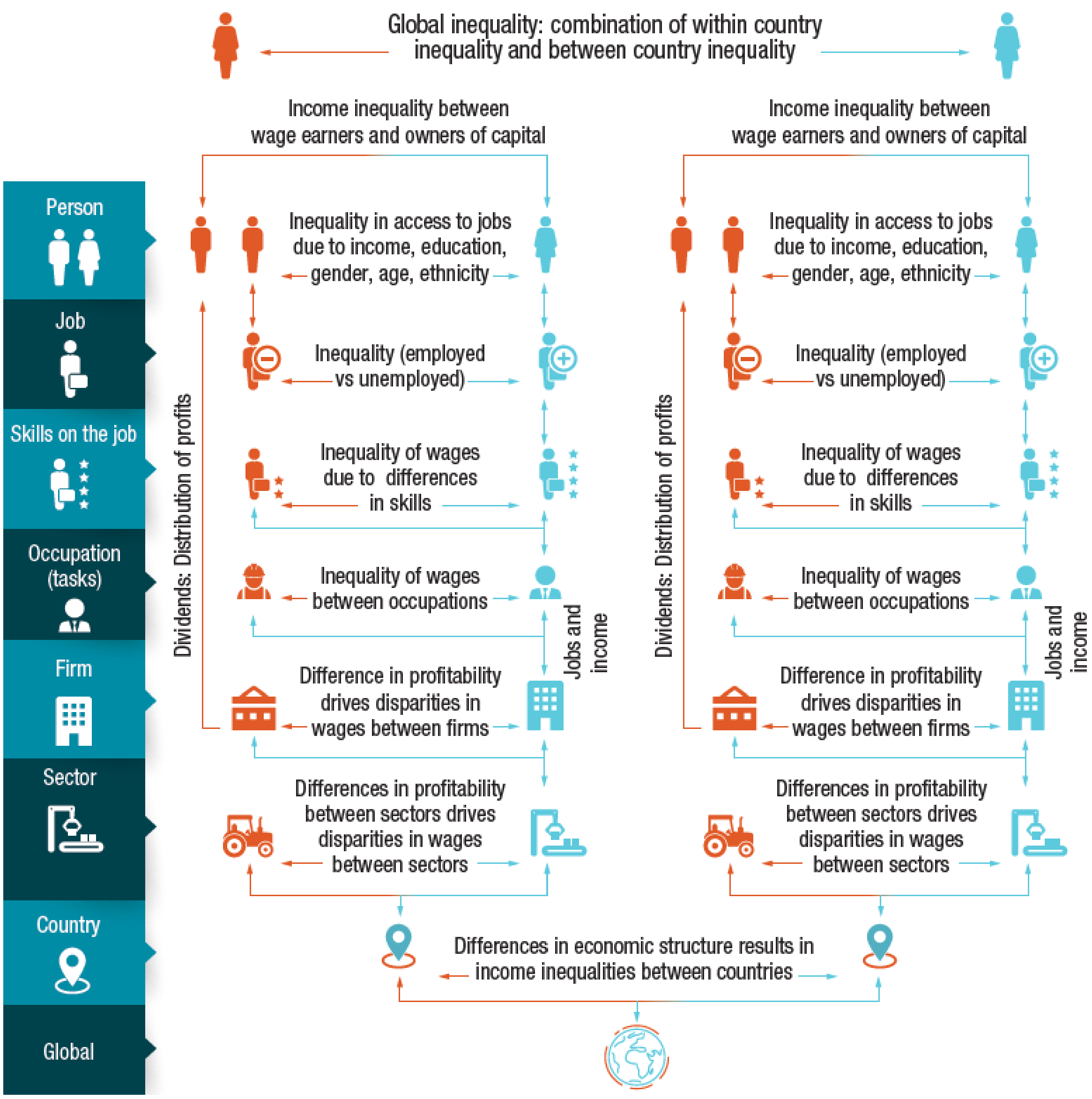
Income inequalities also emerge between wage earners and owners of capital. Profits of firms are distributed to investors through dividends. White-collar workers in some firms can also be remunerated with equity (shares of the company) as part of their compensation and thus also become

[10] For a discussion on how Industry 4.0 technologies could affect inequalitie strhouhg the production lens, see Chapter 4 of UNCTAD's Technoloy and Innovation Report 2021 on "Innovation with equity."

capital owners. Increasing financialization of the economy and potential conflict of interest in the determination of executive pay in large corporations are significant factors in labour income inequality (Lin and Tomaskovic-Devey, 2013). However, how profits are divided between labour and capital depends on social and economic frameworks, how different groups in societies negotiate the division of power and the levels of income and wealth inequality that are considered tolerable.

At the same time, vertical (rich vs poor) and horizontal inequalities (between groups defined by cultural or personal characteristics) affect the access of people to education and their choices of occupations, firms and sectors to work, which therefore affect their opportunities to work and levels of income. For example, in some places and family situations, only the boys are sent to school while the girls stay at home helping with the household tasks; thus, these girls will not have the same access to education and opportunities to develop skills required to get a job. In another example, some industries such as construction and mining may be considered in some countries as sectors of male occupations, and women may decide not to work in these sectors, reducing their options of jobs.

Figure IV-1. Inequalities in the production's perspective



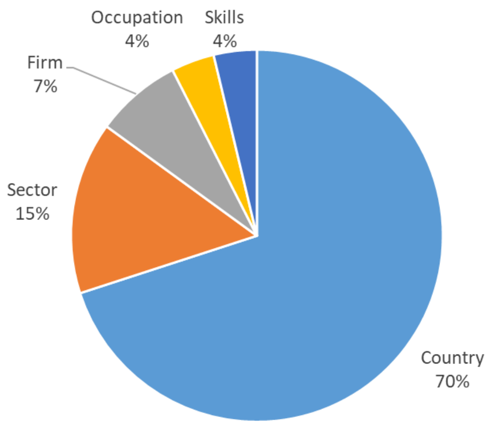
Source: UNCTAD (2021a).

Another level in which inequality emerges is in the differences in the economic structures of countries. The sectors in a country and their contribution to output and employment characterize the country's economic structure and level of productive capacity and, therefore, its average productivity and income. Thus, differences in economic structure drive inequalities between countries.

The contribution of each of these elements to income inequality in a particular country is conditional on many factors, such as labour, social and economic policies, the level of development of the country considered, or the size of the sector and the firms. For example, a study of inequality in the United States from 1978 to 2013 found that two-thirds of the rise in the disparity of earnings was due to an increase in the dispersion of average earnings between firms, compared with one-third of the rise that occurred within firms (Song et al., 2019). In contrast, another study using data for Sweden found a smaller contribution from between-firm differences in wages, which the authors attribute to the Swedish labour market institutions in reducing the scope for variation in wages between firms through collective wage agreements (Akerman et al., 2013). Yet another study examining the large decrease in earnings inequality in Brazil between 1996 and 2012 found that firm effects were not only significant but also positive; they accounted for 40 per cent of the total decrease in inequality, particularly through a decline in firm productivity-pay premium (Alvarez et al., 2018).

Nevertheless, the literature can provide a rough idea of the average magnitude of the contribution of each of these levels. Estimates suggest that, in general terms, the country of birth explains around 70 per cent of the variation in global incomes, which is tremendously relevant not only by that magnitude but given that 97 per cent of the world's population remain in their country of birth (Milanovic, 2015). Sector level inequalities contribute about 20 per cent of income differences with country, while firm-level differences explain around 10 per cent. Differences in occupation and skills, as measured by levels of literacy and numeracy, account for around 10 per cent of the cross-country differences in incomes (Devroye and Freeman, 2001)(Figure IV-2). Therefore, for Governments of the least developed and low-income developing countries, a focus on reducing sectoral inequalities and across country inequality would be more effective. For countries at the technological frontier, focusing on reducing firm and occupational inequality would result in higher gains.

Figure IV-2. Contribution of different levels of analysis for income inequality (production's perspective)



Source: UNCTAD based on Milanovic (2015) and Devroye and Freeman (2001).

In the case of Industry 4.0 in manufacturing, new technology is used mainly in process innovation to increase productivity. Therefore, the initial direct impact of the technological change is on the inequality of firms' productivity within sectors and the disparity of wages due to changes in occupations and tasks.

Manufacturing firms that deploy Industry 4.0 and introduce new products can claim higher profits than other firms in the same sector due to temporary monopolistic situations of being the only providers of a new good or service. Process innovation using these new technologies is expected to save labour and reduce costs and potentially prices, increasing market shares and profits. These higher profits, either through product or process innovation, could spillover to higher average wages in the firm, contributing to income inequalities within the production system. At the same time, these Schumpeterian rents (higher profits that innovators earn) are a critical incentive for innovation. In most sectors, however, although innovation creates winners and losers among firms, the inequality is not permanent. Competition creates incentives for other firms in the same industry to adopt Industry 4.0 for Smart production, and the differences in firms' profitabilities will tend to reduce.

The introduction of Smart production can create, change or replace occupations within a firm. A hypothesis of how technology is incorporated into occupations is the skill-biased technological change, in which technology complements skilled workers (Acemoglu and Autor, 2011a). In this process, higher skills would be associated with higher gains from adopting Industry 4.0 technologies in manufacturing. Despite its success in explaining many decades of data, the skill-biased technological change hypothesis cannot explain the recent phenomenon of job polarization (Michaels et al., 2013; Goos et al., 2014), which is seen in a range of developed countries (Graetz and Michaels, 2018; Dauth, 2014; Autor et al., 2015). A competing hypothesis is the routine-replacing technological change, which predicts an increased demand for labour in non-routine relative to routine tasks (Acemoglu and Autor, 2011b; Autor, 2013; Autor and Handel, 2013). Therefore, Industry 4.0 in Smart production is also expected to benefit workers performing non-routine tasks, both in manual and cognitive jobs, which can affect both high- and low-paid jobs, while workers performing routine tasks are expected to face further pressures from ever more capable machines and AI software.

At the global level, countries with more manufacturing sectors in which more firms adopt Industry 4.0 could expect to experience a higher increase 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.

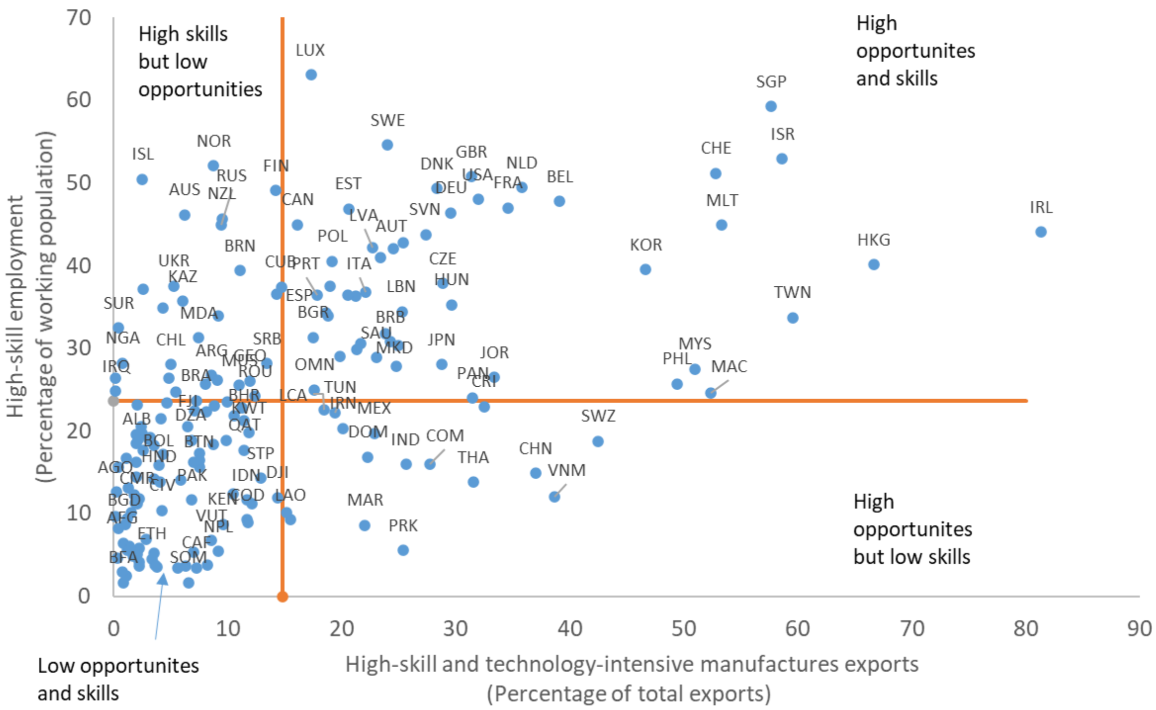
Therefore, assuming that Industry 4.0 will be deployed first in high-skill and technology-intensive manufacturing sectors and will require high-skill workers, we can examine which countries may be initially better positioned to benefit from the diffusion of these technologies for Smart production, and assess if that pattern would tend to reduce or increase inequalities between countries. Figure IV-3 illustrates a simplified attempt of that analysis by presenting how countries perform in high-skill and technology-intensive manufacturing exports (as a percentage of total exports) and high-skill employment (as a percentage of the working population). The orange lines in the figure represent the global averages in these two indicators. They divide the countries into four groups. The first is the group of countries with high opportunities for diffusion of Industry 4.0 due to their specialization in high-skill and technology-intensive manufacturing and a large share of high-skill employment. The United States and many countries in Europe, East and South-East Asia are in this group. Eight economies in the top right part of the figure have above-average performances and maybe benefit the most from Industry 4.0 in manufacturing relatively to their population and exports. These are Ireland, Israel, Malta, the Republic of Korea, Singapore, Switzerland, as well as Hong Kong, China and Taiwan, Province of China.

In the right bottom quadrant of the figure, the second group of countries have high opportunities given their share of high-tech exports but also have a below global average share of high-skill employment, indicating that they may find lack of skills as a significant obstacle in diffusing more broadly Industry 4.0 in manufacture. China, India, Mexico, Thailand, and Viet Nam are some countries in this group.

A third group is composed of countries with above global average shares of high-skill employment, indicating the potential for workers to adapt to Industry 4.0 in manufacturing but low opportunities in terms of firms in high-tech sectors. In this case, these countries may find it difficult to broaden Industry 4.0 in manufacturing beyond the pockets of high-skill and technology-intensive manufacturing sectors. Developing countries with a higher reliance on commodities in their economic structure, such as Argentina, Brazil, Chile, Kazakstan, and Nigeria, are in this group.

The fourth group comprises countries with below the global averages in both indicators. They neither have many high-tech sectors in their economic structure nor the high-skill jobs; thus, Industry 4.0 diffusion would be slower. Most developing countries are in this group. Therefore, this analysis suggests that initial diffusion on Industry 4.0 is more likely to increase inequalities between countries.

Figure IV-3. Which countries may be initially better positioned to benefit from the diffusion of Industry 4.0?



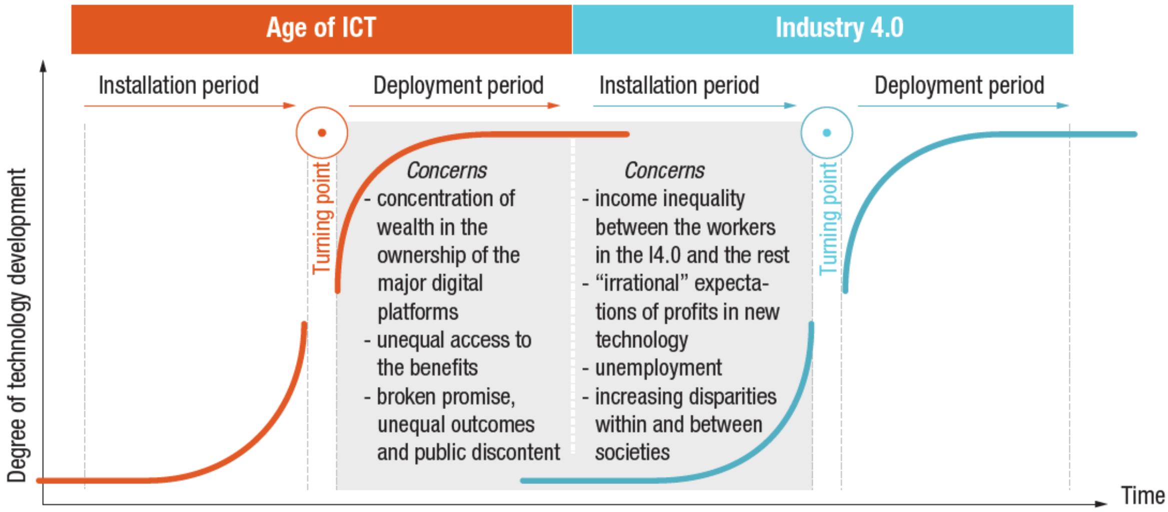
Source: UNCTAD based on data from UNCTADStat and ILOStat.

Note: The orange lines in the figure represent the global averages in these two indicators.

B. Industry 4.0 technological revolution and its effects on inequalities

Many crises and long term factors affect inequality: wars, epidemics, the effects of trade and globalization. One of these long term factors is the impact of technological revolutions. The framework of the interrelation between technological revolutions and financial capital (Perez, 2002, 2010) highlights how different phases in the surge of a new techno-economic paradigm could affect inequalities in the countries at the centre of the technological revolution. The two main phases are the installation period of a new paradigm, which is driven by the supply of innovations in the core industries exploring potential solutions with the new technologies, and the deployment period, in which the new technology is applied to other sectors (Figure IV-4).

Figure IV-4. Technological revolutions and inequalities



Source: UNCTAD (2021a).

The first stage entails the installation of the new technological paradigm, which starts in a few sectors (and places) at the core of the technological wave, such as the tech sector in silicon valley during the installation of the Age of ICT. In this phase, there is the potential for increasing income inequality between the workers in the core industries of the new paradigm, including finance, and the rest. In particular, the financial sector fuels "irrational" expectations of profits in the new technology sectors and could decouple from the real economy in search of increasingly higher gains. The final part of the installation period could be, thus, marked by stark inequalities. The decoupling of finance and productive capital leads to financial crises that pave the way for changes in society and institutions to adapt to the new techno-economic paradigm.

The following deployment phase tends to be a time of more equitable participation in the economy's growth and on the distribution of gains. However, when the new technologies are already part of society and economy at the end of the deployment phase, it could be a time of social discontent when people realize that the promises of social progress through new technologies have left many people behind. It is also the end of a period of merging and concentrating power in a few firms in the core of the paradigm, which gives rise to great fortunes in the hands of a few.

Applying this framework to the present moment, the impact of Industry 4.0 on inequalities would depend if we are indeed living the beginning of a new techno-economic paradigm or if Industry 4.0 is a continuation of the Age of ICT.

In the first case, one could consider that people in countries at the technological frontier live at the end of the deployment phase of the techno-economic paradigm of the "Age of ICT" and start the installation phase of the new Industry 4.0 paradigm. Therefore, this could be a time of discontent with the unequal outcomes and the broken promises of widespread progress through ICTs. This discontent is further fueled by the enormous concentration of wealth by the owners of the major digital platforms. At the same time, there are already concerns about the possible impact on inequality of the new technologies. Such impact has not materialized yet, given that the new paradigm is still in its early stages. Still, people already foresee the many ways that it could increase disparities through its impact on production and consumption.

For developing countries, the installation of a new technological paradigm has been historically a window of opportunity for some countries to catch up and others to forge ahead. For example, Fagerberg and Verspagen (2021) show that in the "Age of ICT," some countries in Asia were able to catch up technologically and economically by developing capabilities to enter the ICT sector (hardware and software), the core sector of that techno-economic paradigm, and experiencing a structural change in the direction to technology-intensive export sectors. Therefore, the installation phase of Industry 4.0 could be when countries that enter sectors associated with the new paradigm could experience higher growth and catch up with the technology frontier. Thus, under this scenario, we may see in the next couple of decades an increase in within-country inequality in countries at the technological frontier, and at the same time, some developing countries catching up and others forging ahead, reducing inequality across countries. Nevertheless, most developing countries would still be trying to catch up with the previous technological paradigms, let alone Industry 4.0.

In the second scenario, we could consider Industry 4.0 as a continuation of the Age of ICT, as the deployment of the digital and connectivity paradigm more broadly in other sectors of the economy. In that scenario, there could be a golden age of increasing prosperity in developed countries, with the increase in productivity experienced in the tech sectors now being also experienced in other (more traditional) sectors of the economy through the diffusion of Industry 4.0. But while this could be a period of more shared prosperity in developed countries, this could also be a period of consolidation of the technological gap between countries at the technological frontier and the rest. Historically, catch up trajectories tend to occur in the installation phase of the technological paradigm, not in the deployment stage. Thus, in this scenario, there would be a reduction of inequality within countries at the technological frontier and, at the same time, a persisting gap across countries.

Both scenarios offer a gloomy prospect for most developing countries unless they take effective action, supported by the international community, to promote and support further diversification of their economies towards more technologically intensive processes and industries while, at the same time, trying to enter into the sectors associated with the new technological paradigm.

V. Specific challenges

In addition to the potential increase in income inequality between countries due to the temporal and geographic disparities in the diffusion of Smart production, Industry 4.0 brings some specific potential challenges in various aspects. At the centre of these challenges are two features of the technologies that consist of Industry 4.0 (UNDESA, 2020):

a) The labour-saving feature of the Industry 4.0 technologies allows employers to produce the same amount of output with less labour (substituting labour with capital) symbolically through automation, hence reducing the need for labour; and
b) The skill-biased feature of the Industry 4.0 technologies requires relatively high skills to utilize the technologies. Hence, the productivity and demand of high-skilled workers rise more than lower-skilled workers.

A. Displacements of workers and wage inequality

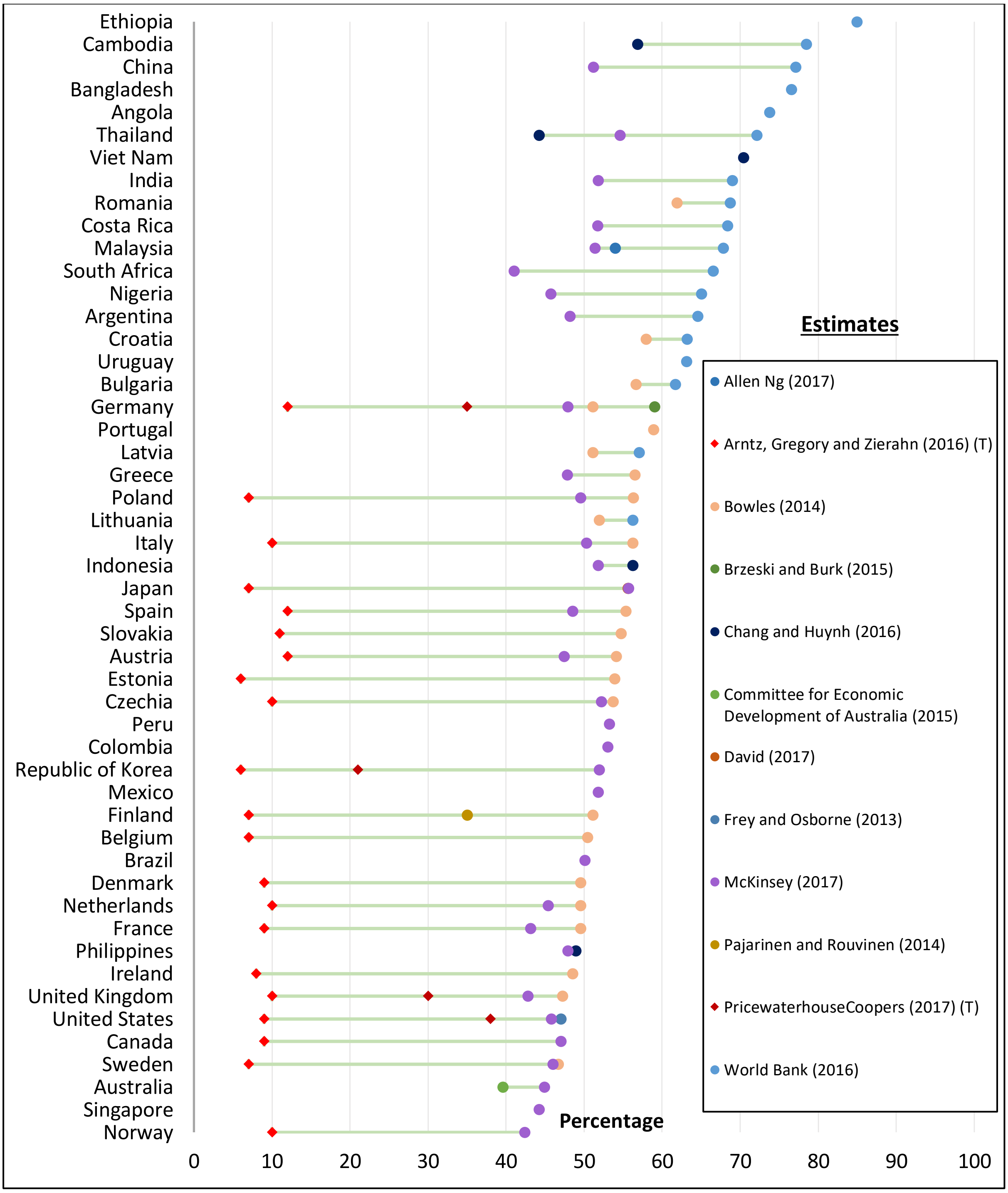
Due to the labour-saving feature, there has been a proliferation of predictions about how many jobs will be lost due to the Industry 4.0 technologies. Most estimates conclude that there is a risk that many jobs will be lost, and the risk is particularly more acute for the developing countries, which tend to have more routine-type jobs (UNDESA, 2020) (Figure V-1). For instance, World Bank research suggests that two-thirds of all jobs are susceptible to automation in the developing world (World Bank, 2016). In developed countries, most estimates suggest that middle-skilled jobs that are more routine-based carry a higher risk of disappearing (UNDESA, 2020).

However, most alarmist scenarios do not consider that not all tasks in a job are automated and, most importantly, that new products, tasks, professions, and economic activities are created throughout the economy (UNCTAD, 2021a). Job displacement could occur initially (in partial equilibrium), but when looking at the longer-term (in general equilibrium), the new technologies themselves could bring new demands and hence create more jobs as in previous Industrial Revolutions.

In fact, there are several compensatory effects that are not considered in these assessments. For example, employment could increase via 1) additional employment in the capital goods sector, 2) a decrease in prices, 3) new investments, 4) a decrease in wages, 5) an increase in incomes, and 6) new products. Vivarelli (2014) highlights that the compensatory mechanism via new products is the most powerful way to counterbalance labour-saving tendencies of process innovation. In relation to the impact of technological change on developing countries, Vivarelli notes that the main channels of effect are trade and foreign direct investment and technology transfer, which depend on the absorptive capacity of countries.

The displacement could also happen at the level of tasks that belong to workers rather than workers themselves, which could lead to, for instance, the automation of manual and routine tasks while keeping the workers themselves in the workforce (UNIDO, 2019). While developing countries, in general, might suffer more from automation, countries have different factor endowments, comparative advantages and sector compositions and combined with the uncertainty as to which sectors are more prone to job displacement (manufacturing sectors could be more prone to automation by robotics but service sectors also have risks of automation by AI and other technologies), the overall effect might not be as straightforward as estimates would suggest (UNIDO, 2019).

Figure V-1. Estimates of the share of jobs at risk of being lost to automation as a result of artificial intelligence and advanced technologies, by study

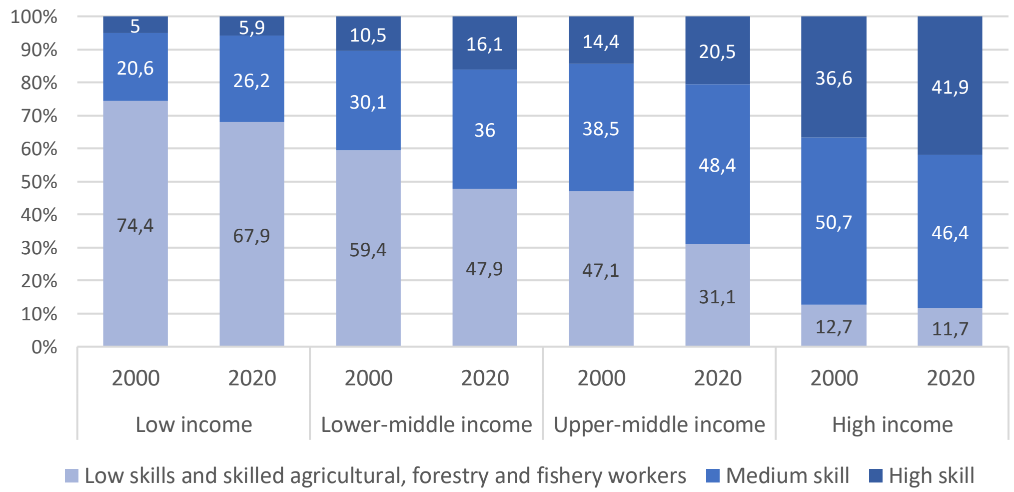


Source: (UNDESA, 2020; Ng, 2017; Arntz et al., 2016; Bowles, 2014; Brzeski and Burk, 2014; Chang and Huynh, 2016; Committee for Economic Development of Australia, 2015; David, 2017; Frey and Osborne, 2017; McKinsey Global Institute, 2017; Pajarinen and Rouvinen, 2014; Berriman and Hawksworth, 2017; World Bank, 2016)

Empirically, there has not been strong evidence that suggests large-scale job displacements due to Industry 4.0 technologies as indicated by estimates. In fact, at least in the United States, where the adoption of Industry 4.0 technologies is advanced and also the home to the world-leading technology companies, labour productivity growth has slowed down in recent years, which is the opposite of what estimates would suggest as the replacement of labour with capital should increase labour productivity per worker (Krugman, 2021). In the United States, the first months of the COVID-19 pandemic saw some trends of increasing automation due to the shortage of labour, but the mid- to long-term effect and persistence of the trend remains to be seen (Ding and Molina, 2020).

Aside from the displacement of workers, Industry 4.0 technologies could also have the potential of affecting wage inequality. The skill-biased nature of technologies would create more demand for high-skilled workers while less demand for lower-skilled workers, pushing up wages for high-skilled workers whereas lowering wages for lower-skilled workers. This difference in wages of high-skilled and low-skilled workers, so-called skill premium or return to education, has been widening in the last decades despite the growth in educational attainments in the workforce (UNDESA, 2020). This leads to the belief that the speed of technological development has been faster than growth in educational attainment ("the race between technology and education") as higher educational attainment should reduce the skill premium. As discussed in the previous section, on average, higher-income countries have a larger percentage of high-skilled workers while lower-income countries have a larger percentage of low-skilled workers (Figure V-2); thereby, the widening skill premium due to Industry 4.0 would work in disadvantage to lower-income countries on a global level.

Figure V-2. Employment by skill level (percentage of total civil employment)



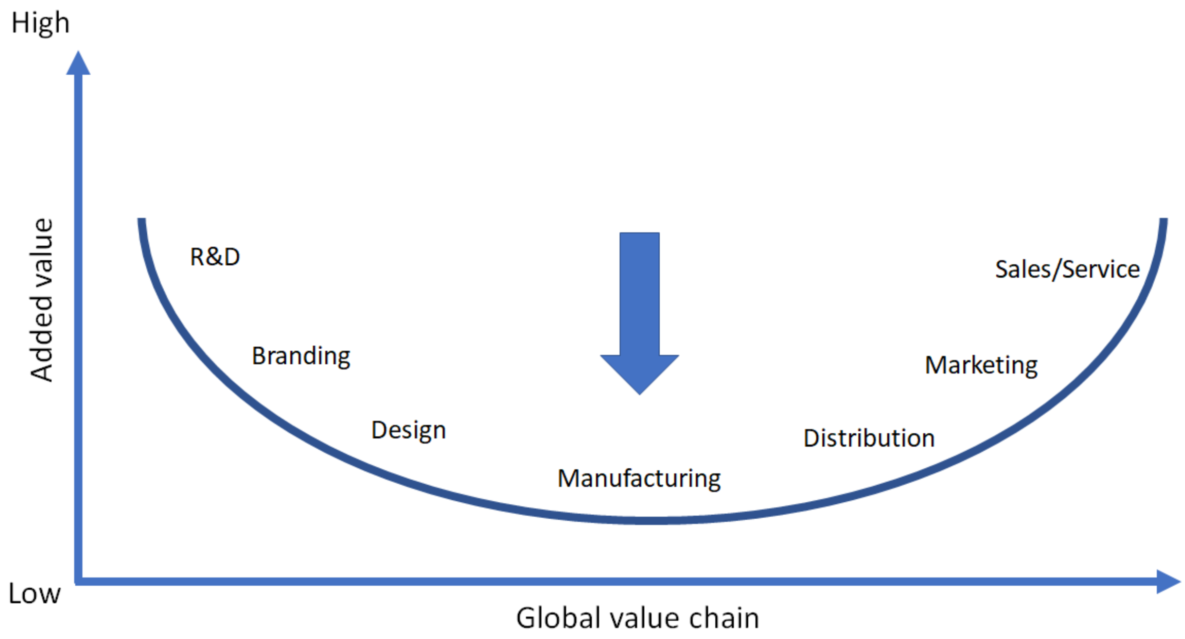
Source: UNCTAD, 2021a.

At the same time, it is important to note that the assumption on which this argument is based is that wage always equals workers' productivity or skill level. However, there are also other determinants of wages. For instance, the declining membership of labour unions and weaker bargaining power would lower workers' wages at given productivity (UNIDO, 2019). Also, dominant employers could pay lower wages to their employees, exercising their monopsonistic power in the labour market. Also, on the higher end, there has been the emergence of superstar managers who are considered high-skill, but their wages are so high that their productivity alone might not justify the level of their wages (UNDESA, 2020). All these could factor into the rising skill premium, and hence the net effect of technological development on rising skill premium is difficult to measure.

B. Re-shoring of production and restructuring of FDI and GVCs

With the emergence of Industry 4.0 technologies, the landscape of FDI and GVCs might change. Due to the labour-saving technologies, labour intensive work in developing countries could be replaced by technologies such as robotics and AI in developed countries, reducing the former's comparative advantage in manufacturing within GVCs that could lead to re-shoring production from developing to developed countries (UNCTAD, 2018a). From the developed countries perspective, Industry 4.0 technologies could sharpen their comparative advantage in skills- and capital-intensive industries, including intangible components which have become more prevalent due to digital technologies (UNCTAD, 2018a). All these effects combined could deepen the "smile curve" of GVCs, with developed countries ending up adding more value while developing countries losing their share of value addition within GVCs (UNCTAD, 2018a) (Figure V-3).

Figure V-3. Deepening of global value chain smile curve



Source: UNCTAD compilation based on (UNCTAD, 2018a)

On the other hand, arguably, the firms' FDI decisions are based not only on labour cost but also on other multiple factors such as market access, favourable policy environment and incentives. Whether the re-shoring would occur also depend on factors more related to implementation, such as switching costs, inertia and coordination complexity associated with re-shoring (UNCTAD, 2018a). In addition, digital technologies could also encourage the participation of more firms in GVCs through bridging distances and reducing costs related to trade and assembly (WTO, 2019).

Empirically, the FDI growth rate and the GVCs expansion have slowed after the global financial crisis in 2008, and technological development has been named as one of the factors of this trend. However, the degree to which technology has contributed to the slowdown of FDI growth is uncertain as there are other factors such as a return of protectionist policies, a gradual decline in the return on FDI over the decade and increasing adoption of non-equity (non-ownership) modes of production such as contract manufacturing, production under license and international franchising particularly in consumer goods and retail (UNCTAD, 2020). Indeed, a recent ILO study argues that re-shoring remains a rare phenomenon, but they also found an association between the adoption of Industry 4.0

technologies in developed countries and re-shoring (ILO, 2020). UNIDO (2020) also reports empirical evidence from 2,500 firms from eight European countries (Austria, Croatia, Germany, the Netherlands, Serbia, Slovenia, Spain and Switzerland), showing that reshoring is not common: only 5.9 per cent of those firms have reshored, while 16.9 per cent have offshored. Moreover, labour costs were not the main reason for reshoring from emerging economies but flexibility in logistics.

C. Protecting workers in Industry 4.0 era

Similar to the previous Industrial Revolutions, an expected main character of the Fourth Industrial Revolution is the boost in productivity. Thanks to the development of AI, IoT, and big data, the Fourth Industrial Revolution can achieve this by managing the workforce more effectively. At the core of this are a large amount of data collected using wearable devices, GPS, ratings and evaluations by users and logs on the computers and systems on workers' performance and behaviours, combined with analyses conducted by algorithms and AI (Stefano, 2018). While the use of technologies for such people analytics practices can be based on genuine business needs, and they have the potential to improve productivity and enhance the benefit of employees, there are several concerns.

First, surveillance and monitoring practices can lead to severe intrusion into workers' privacy (Stefano, 2018). Also, algorithms could be developed based on a narrow vision of productivity and efficiency (often to implement just-in-time work practices) without taking into account numerous hidden costs associated with the tasks, resulting in failing to capture the true performance of the workforce. Moreover, the algorithms and AI, particularly the self-learning ones, are prone to discrimination and unneutral outcomes. They are easy to manipulate, may be biased, reflect cultural, gender and other prejudices and preferences and may contain errors with little transparency (UNCTAD, 2021a). Given these concerns, there have been collective agreements in various countries that regulate the use of technology in monitoring workers and directing their work, aiming to reserve human dignity and health and safety of workers, although the efforts are still at an early phase (Stefano, 2018; De Stefano and Aloisi, 2018).

D. Gender implications of Industry 4.0

Industry 4.0 could bring about important changes in power, knowledge, and wealth and may impact the pursuit of gender equality. For example, there are nearly four times as many women employed as clerks or service workers (26 per cent as opposed to 7 per cent for men), which are occupations that are considered more likely to be replaced by computers and automation. Will the Fourth Industrial Revolution be "gender-blind"? It is critical to examine what impact or shape Industry 4.0 might have through a "gender lens." How will society, and women, in particular, be affected by this accelerated pace of technological change?

According to Brussevich et al. (2018), given the current state of technology, 10 per cent of the workforce or 54 million workers in 30 countries (28 OECD member countries, Cyprus, and Singapore) is at a high risk of being automated and displaced by technology within the next two decades. A larger proportion of the female workforce is at high risk for automation than the male workforce (11 per cent versus 9 per cent), with 26 million female jobs potentially at stake in these countries. As discussed in section V.A, these estimates have to be taken with a grain of salt given the failure to account for new jobs and other compensatory effects; nevertheless, this illustrates the fact that women are usually more at risk of being displaced than men.

Since Artificial Intelligence (AI) permeates the entire industry and is at the forefront of Industry 4.0, it is particularly useful to look at trends in the sector concerning gender. Machine learning data, algorithms, and other design choices that shape AI systems tend to reflect and amplify existing biases and prejudices, especially in the area of gender. This is so because women are underrepresented in

AI. A 2020 World Economic Forum report on gender parity, for example, stated that women account for only 26 per cent of data and AI positions in the workforce. While higher concentrations are reported in Singapore, South Africa and Italy, it is still below 30 per cent, with many countries reporting 18 per cent or less of females in AI (World Economic Forum, 2018).

To be able to address how Industry 4.0 can narrow the gender gap, the effects of new technologies need to be better understood, particularly AI. They can have real potential to reverse momentum in gender equality through effects on women's employment and labour force participation, access to financial resources and can therefore affect their economic and livelihood opportunities.

VI. Harnessing Industry 4.0 for inclusive and sustainable development

This section discusses what governments, the private sector, and other stakeholders should do so that developing countries can benefit from Industry 4.0, contributing to their national development priorities and accelerating the progress towards the SDGs. The section further illustrates the main policy recommendations with concrete examples provided by CSTD member countries and the UN System on the strategies, policies, programmes, and policy instruments focusing on Industry 4.0.

Several developing countries have actively undertaken digitization of industry and started at least a partial adoption of Industry 4.0 technologies. However, governments face various challenges related to infrastructure, support institutions, appropriately skilled labour, and a general preparedness of key industries.

A challenge that governments face regarding the preparedness of their industries is the imperative that they cultivate an understanding of future scenarios and remain informed about the potential implications, opportunities, and risks ahead. There is also the challenge to ensure that adequate infrastructure, including energy and ICT, is in place to support the adoption and implementation of Industry 4.0, enabling the country to reap the benefits of technological change. Other challenges that governments may face for promoting Industry 4.0 to accelerate the progress towards SDGs relate to a widening technology and knowledge gap, its implications on skills, rising inequalities, and gender equality which will need to be managed to increase societal acceptance for change.

Strategic responses to the deployment of Industry 4.0 technologies are highly contextual, reflecting the country's level of industrialization, digital infrastructure, technological and productive capabilities, and national priorities and capacities for resource mobilization (UNIDO, 2020).

- Developed countries with advanced manufacturing bases are already at the frontier of technological adoption. They have focused their policy responses on sustaining and regaining manufacturing leadership.
- Emerging developing countries, in their turn, have sought to narrow the technological gap, increase competitiveness and expand their participation in higher-value-added parts of GVCs. Their policy responses have focused on fostering innovation and technological adoption in their manufacturing sectors. Some of these countries have firms at the technological frontier that have deployed or are ready to deploy Industry 4.0. A challenge is to facilitate the deployment in more traditional manufacturing sectors of the economy.
- Less technologically advanced and less diversified developing countries have fewer sectors exposed to the deployment of Industry 4.0 and lower technological and innovation capacities in general. These countries should focus on diversifying their economies, increasing the share of manufacturing in total output, and setting the required conditions of digital infrastructure and skills to get ready to deploy Industry 4.0 (UNIDO, 2020).

The following sections discuss critical policy areas that stakeholders in developing countries, regardless of their technological level, should consider facilitating the deployment of Industry 4.0 in manufacturing to reduce technological and income inequalities between countries and ensure that it contributes to reducing inequalities within countries.

A. Tackling the pre-conditions for Industry 4.0

Developing countries would not be able to broadly harness Industry 4.0 for development if they do not have the essential pre-conditions of Industry (manufacturing) and digital infrastructure and skills.

In the absence of these elements, at best, only a few firms in a developing country will use Industry 4.0 technologies, and even fewer will adopt Smart production.

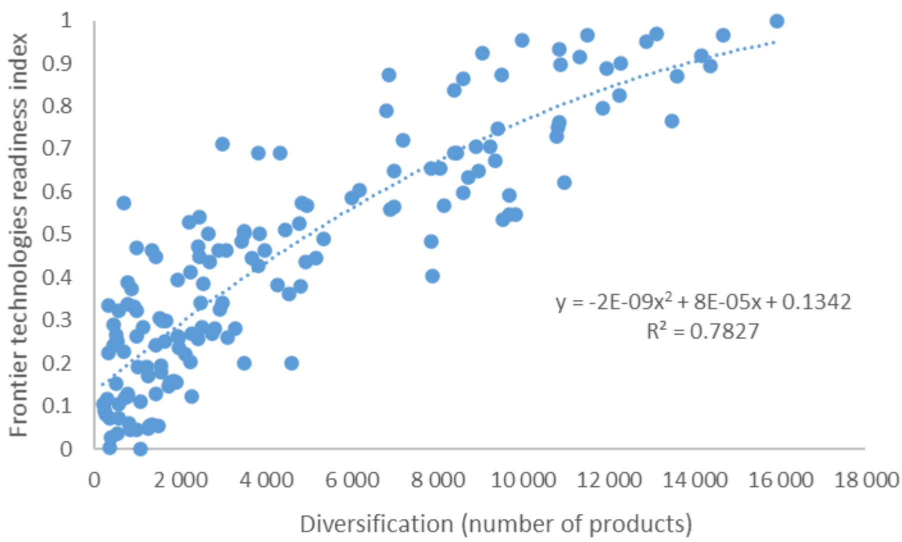
While working to have the Industry 4.0 pre-conditions in place, developing countries should develop the framework conditions required to deploy Industry 4.0 in manufacturing (UNIDO, 2020). These include the development of national strategies that direct, in a coherent and coordinated manner; the development and deployment of Industry 4.0, the creation of a multistakeholder mechanism that institutionalizes a participatory approach to foster Industry 4.0, building international cooperations to accelerate transference of technology and know-how, and setting an enabling intellectual property regime.

1. Diversifying the economy and building a manufacturing sector

As discussed in sections III and IV, the diffusion of Industry 4.0 is only beginning in developed and emerging countries. It is still a much further way to become a reality in the production structure in developing countries, particularly low-income and least developed countries. The reason is that these big waves of technological change actually behave like waves that start in one or two of the most technologically advanced countries and then begin to spread around the world; first to other advanced economies, then to more complex sectors of emerging economies, and only after a long time, they move to the more peripheral economies.

One reason is that less diversified developing countries have their production structure very far from the core sectors of the new technological paradigm (e.g. computers and digital products), and it will take a longer time for them to deploy the new technology in their production base if they do not diversify their economies. In fact, high diversification is associated with higher readiness to use, adopt and adapt frontier technologies, based on UNCTAD's index (Figure VI-1). Therefore, promoting diversification can facilitate the deployment of the new technological wave.

Figure VI-1. Association between UNCTAD's frontier technology index and diversification of economies, 2019



Source: Freire (2021).

Note: Diversification is based on the number of product categories exported at the SITC 5-digit level further disaggregated by unit value using the methodology presented in Freire (2017).

To successfully facilitate the broad diffusion of Industry 4.0 and harness its benefits, developing countries need to diversify their production bases by mastering existing technologies (automation machinery and equipment); otherwise, they risk being left behind. This approach depends on the level of economic development of each country and its economic structure. In practice, the focus of a country's policy framework should be on the policy objectives that are more related to their installed production base and the maturity of the technology that they use. For example, less diversified countries may focus more on diversifying their economies and technological learning and mastering the technologies of the sectors in which the country is trying to promote for increasing jobs and value addition.

In this regard, developing countries, and low-income and the least developed countries, in particular, should go back to the basics of economic development, giving a focus on their development strategies and programmes in diversifying their economies, shifting output and employment of their economic activities from low-value-added sectors to high-value-added ones. The State has a crucial role in pushing for and facilitating the emergence of productive capacities in the Industrial sector, particularly, but not necessarily exclusively, in the private sector. Governments need to facilitate business' identification of and entry into potential sectors for diversification, promote key potential new sectors of national interest (e.g. targeting job creation, food security, energy security, industrialization, digital transformation), strengthen the effectiveness of their innovation systems to support diversification, build coherence between science, technology and innovation policies and other economic policies (industrial, trade, fiscal and educational policies), and involve a wide range of actors. The concerns with the impact of production on the environment and the risks of climate change should also be put at the centre of these strategies and programmes, promoting diversification and technological upgrading towards greener manufacturing and a circular economy.

2. Developing the digital infrastructure

Digital infrastructure is a pre-condition to promoting the use, adoption, adaptation and development of Industry 4.0 technologies by enterprises and businesses, including SMEs. Physical infrastructure coupled with digital technologies allows the economy to digitalise its economic activities (Brennen and Kreiss, 2014). The deployment of Industry 4.0 technologies requires digital infrastructure, platforms and data. Digital infrastructure is complex and generally includes (i) ICT networks (the core digital infrastructure for connectivity); (ii) data infrastructure (data centres, submarine cables and cloud infrastructure); (iii) digital platforms; and (iv) digital devices and applications (UNCTAD, 2019b).

The quality of the internet directly affects developing countries' ability to use digital technologies. Also, when examining the relationship between broadband availability and skills upgrading in Africa, there is evidence that fast Internet led to productivity improvements in countries such as Ethiopia (and increases in exports from several countries) (Hjort and Poulsen, 2019). Decreasing telecommunication costs and speedier Internet connections can enable SMEs to overcome information-related barriers to entry and market failures.

However, there is a substantial digital divide at the global level between developed countries and developing countries and between developing countries and LDCs (Banga and te Velde, 2018). This affects disparities between countries, as manufacturing activities are becoming gradually digitalised, further increasing the trade competitiveness of the developed countries (UNCTAD, 2017). Small firms in LDCs only attain 22 per cent of the connectivity score of large firms in LDCs, compared to 64 per cent in developed countries (ITC, 2015). A persistent lack of Internet access hampers the development of SMEs in developing countries, creating unequal competitive conditions compared with their developed country counterparts (ITC, 2021). In addition, firms in many low-income developing countries also face significant electricity constraints that impact their ability to use the Internet, with operations severally restricted due to frequent power outages, as happens in many countries in SubSaharan Africa.[11]

The extent of digitalization also varies significantly across developing and least-developed countries. For example, In Senegal, while Internet is widely available among large firms (75 per cent of them have Internet access), just over a third (34 per cent) of firms with more than five employees have access to the Internet (Cirera, Comin, Cruz, et al., 2021). In fact, many companies in Sub-Saharan Africa are not connected to the web (Guerriero, 2015). compared to Asian countries, African countries, on average, have significantly lower download and upload speeds while facing higher delays in processing network data (Banga and te Velde, 2018). Furthermore, the LDCs are largely not making productive use of broadband technologies (ITU, 2021).

Even easy access to the Internet does not necessarily mean that companies will embrace new Industry 4.0 technologies. The experience with the diffusion of e-commerce illustrates that. The results of sector-specific surveys carried out in 2004 in Bangladesh, Egypt, Kenya, Morocco, Nigeria, Senegal, South Africa and Uganda suggest that while Internet access was relatively high among businesses, the adoption of e-business was low (UNCTAD, 2004). In 2021, a survey in Viet Nam offered similar results, where despite almost universal access to the Internet, the percentage of firms with their own website, social media, and cloud computing is still small (Cirera, Comin, Marcio, et al., 2021). This highlights the challenge of low technological and innovation capacity in developing countries. Many developing countries with low levels of technological development have only limited mechanisms to induce the adoption of new technologies.

Governments in developing countries should work towards providing their business sector with affordable, high-quality access to the Internet. Key policy aspects include the mobilization of investment in ICT infrastructure, both public and private, and the creation of a regulatory environment that provides for sound competition in the telecommunications sector. Infrastructure investment should be placed in the context of structural transformation to provide developing countries building their industrial capacities with an alternative perspective on how to plan, execute and coordinate those investments. Governments should also try to bridge the ‘connectivity gap’ between small and large firms in low-income developing countries and LDCs.

3. Building skills for Industry 4.0

Developing countries’ governments need to ensure that businesses, including SMEs, have the digital skills and knowledge to use ICT technologies efficiently in the different business functions such as market research, product development, sourcing, production, sale, or after-sale services (WTO, 2018).

With technology increasing faster than skills, the risk of a skill mismatch is also rising (Banga and te Velde, 2018). There is a need to develop relevant skills and other capabilities in many developing countries to enable the deployment of Industry 4.0 technologies (UNCTAD, 2021a). Developing countries need to build and attract a skilled workforce while minimizing or reversing a brain drain of the talent with such “disruptive” skills to developed countries. Policymakers should consider introducing incentives to retain skilled professionals or attract skilled expats.

For example, South Africa has pledged to increase the number of young people and adults with skills for employment, decent jobs and entrepreneurship. By providing relevant skills required for the digital world, South Africa aims to mitigate the potential number of job losses due to automation and achieve the targets outlined in its National Development Plan (NDP) and the SDGs. Similarly, to prepare a

[11] For example, see Cirera et al. (2021) for a discussion in the context of Senegal.

skilled workforce for Industry 4.0, Kenya is implementing a comprehensive capacity-building programme built around experiential learning (Box VI-1).

Box VI-1. Preparing skills for Industry 4.0

Kenya: Kenya is aware that the next generation workforce of Kenya will be taken up by those that will seize on opportunities provided by frontier and digital technologies in health, agriculture, housing, manufacturing, and environmental issues at the community level. Accordingly, training and mentoring a technology-savvy workforce will require a collaborative effort between training institutions and the industry to expose the next generation STI workforce on underlying principles of technology development as well ethical implications of frontier technologies such as artificial intelligence, quantum computing, machine learning and cybersecurity.

Capacity-building through experiential learning is being undertaken at all levels starting from basic education. Kenya focuses on competency-based education and training (CBET) at pre-primary, primary, secondary, TVET and university levels. Students are being trained, and skilled labour is developed to thrive in the Industry 4.0 environment. Kenya is combining and integrating physical, digital and biological spheres and re-skilling and up-skilling to realize a 'human-centred revolution'.

South Africa: To produce a globally competitive workforce, South Africa plans to develop a super-smart society that leverages robotics, big data, AI, and IoT to deliver services that enhance the quality of lives of all citizens. It plans to create a resilient and digital skilled population that can adapt rapidly to the future digital world. Through investing in R&D activities to provide solutions to South Africa's socio-economic challenges, STI is expected to serve as an enabler that can be harnessed to overcome the digital divide and provide equal access that could result in better employment opportunities among vulnerable groups, as well as stimulate economic growth.

South Africa's funding for digital research has concentrated on building capabilities in STEM. Over the years, South Africa has built capacities through space sciences and cyber-infrastructure in physics, earth science, mathematics, computer science, engineering, big data, supercomputing, cyber-security, e-science and e-research through a variety of postgraduate teaching and training programmes. Through these projects, students develop skills that are essential for Industry 4.0. Investments in data science and mobile applications laboratories to support access to training and skills development for the future digital world have contributed towards inclusive development.

Source: Contributions from the Governments of Kenya and South Africa.

4. Developing national strategies for Industry 4.0

A National Strategy for Industry 4.0 is critical to guide the country's innovation efforts towards developing and deploying Industry 4.0 technologies in manufacturing. A National Strategy identifies investments needed in physical infrastructure and human capacity, including training in the new digital skills required, key sectors that require strengthening capacity, and points to aspects of the regulatory environment that need to change for firms to adopt and adapt the technology.

A strategy for Industry 4.0 could take many forms, either as a stand-alone national strategy, as part of national strategies for industrialization and manufacturing, or science, technology and innovation. In any of these cases, it is critical to align innovation and industrial policies to harness Industry 4.0 for manufacturing. A focus on raising productivity growth will require various industrial and innovation policies, including more collaborative projects. Aligned STI and industry policies should draw firms into the core of frontier technology development resulting in improved levels of labour productivity (UNCTAD, 2021a). This would enable traditional production sectors to access Industry 4.0 technologies benefiting from multiple channels of technology diffusion, including foreign direct investment, trade, intellectual property rights, patents and the exchange of knowledge and know-how (UNCTAD, 2021a).

Examples of countries with a national strategy to adopt advanced manufacturing show that they have sought to deploy Industry 4.0 technologies to maintain or increase their manufacturing competitiveness (Box VI-2). Many countries strive to be among the leaders in the new production regime. The changing skill requirements of the new systems have gotten attention, with the emphasis on technician-level training and broadening STEM skills. The opportunity to spread new manufacturing jobs across unequal regions is part of most of the plans.

Box VI-2. Examples of National Strategies for Industry 4.0

China: "Made in China 2025" is the country's first ten-year action plan focusing on promoting manufacturing. The strategy aims to transform China into a global leader in key high-end manufacturing sectors, drive innovation, and hold competitive advantages by 2049. Nine tasks are priorities: improving manufacturing innovation, integrating technology and industry, strengthening the industrial base, fostering Chinese brands, enforcing green manufacturing, promoting breakthroughs in ten key sectors, advancing restructuring of the manufacturing sector, promoting service-oriented manufacturing and manufacturing-related service industries, and internationalizing manufacturing. The ten key sectors are: 1) New information technology, 2) high-end numerically controlled machine tools and robots, 3) aerospace equipment, 4) ocean engineering equipment and high-end vessels, 5) high-end rail transportation equipment, 6) energy-saving cars and new energy cars, 7) electrical equipment, 8) farming machines, 9) new materials, such as polymers, and 10) bio-medicine and high-end medical equipment.[12]

Brazil: In 2019, the government of Brazil set up the Brazilian Chamber of Industry 4.0 (Chamber I4.0) as an initiative of the Ministry of Science, Technology, Innovation and Communications (MCTIC), the Ministry of Economy and the Brazilian National Federation of Industries (CNI). Chamber I4.0 has set an action plan to introduce concepts and practices related to industry 4.0 to companies, including SMEs, to increase their competitiveness and productivity and contribute to the insertion of Brazil into global value chains. The initiative also aims at ensuring the following: stability and volume of resources at an adequate cost to implement initiatives for Industry 4.0; the development of Industry 4.0 solutions suitable for Brazilian companies and; coordination to avoid overlapping individual efforts by public and private institutions to address needs and Industry 4.0 demands in Brazil. The Chamber has been following the path provided by other governmental plans, including the CT&I Plan for Advanced Manufacturing in Brazil – ProFuturo (MCTIC, 2017) and the National Internet of Things (IoT) Plan (MCTIC and BNDES, 2017).

Colombia: The country's Industrial Policy "Política Industrial en Marcha" seeks to promote the adoption and use of modern technologies to address social and economic disparities, and contribute to higher levels of productivity and competitiveness of its economy. Within this policy, the Government is delivering programmes and action plans for the adoption of new technologies, such as the launch of "The Center for 4IR" to ease the adoption of AI, Big Data, IoT, Blockchain, and Smart Cities, and the initiative "Banco de Retos" to promote the matchmaking between productive processes and local service providers. In addition, the Taxes Law 1955/2019 includes incentives for the investment in science, technology and innovation, and there are credit lines for innovation included in the strategy to use royalties by the Science, Technology and Innovation Fund.

European Union: The EU's Vision 2030 sets out a vision of the European industry in 2030 as a global leader, responsibly delivering value for the society, the environment and the economy (European Union, 2019). The strategy aims to build Europe's competitive advantage on cutting-edge and breakthrough technologies, respect for its environment and biodiversity, investment in its people, and smart European and global alliances. Based on collaboration and common European values, this plan seeks to provide a new industrial model to help to make Europe a role model for the rest

[12] http://english.www.gov.cn/policies/latest_releases/2015/05/19/content_281475110703534.htm

of the world. The strategy is to promote cutting-edge technologies, the automation and digitisation of manufacturing, products and data-driven services, based on sound ethical values, to transform European industry. Progress in AI, IoT, robotics, automation, biotechnology or 3D printing is considered essential to bring about technology-led transformations across all European industries.

Mexico: The country's 2016 Roadmap for Industry 4.0 focuses on the automotive, aerospace, and chemical industries. These accounted for over 900,000 jobs, and the roadmap envisions the growth of jobs in new sectors, including new IoT businesses, talent development for design and engineering, big data analysis, and digital solutions. Training for both engineers and technicians is part of the plan. The roadmap includes regional development: it recommends identifying six states with the potential to implement Industry 4.0 ecosystems and develop plans for Industry 4.0 clusters there.

Thailand: Thailand's National Strategy (2018-2037) is the core development strategy of Thailand. It plans to establish and increase competitiveness in ten industries: new-generation automotive, smart electronics, affluent, medical and wellness tourism, agriculture and biotechnology, food for the future, manufacturing robotics, medical hub, aviation and logistics, biofuels and biochemicals and digital industries. The 20-year Industry 4.0 Strategy (2017-2036) of the Ministry of Industry aims to move the country towards smart industries and strengthen the links to the global economy.

Source: UNCTAD with contributions from UNIDO and the Governments of Brazil and Thailand.

National strategies for Industry 4.0 could also direct innovation to tackle social challenges. For example, the Technology and Innovation Report 2021 presents examples of Industry 4.0 strategies in the context of ageing populations (e.g. Japan), addressing regional disparities (e.g. Mexico and South Africa), and climate change.

To develop a strategy for Industry 4.0, governments should consider the potentially disruptive effects for years ahead, requiring strategic vision and intelligence in the form of technological foresight and assessments. These assessments extract knowledge and evidence from various stakeholders about the industrial growth areas that match a country's strengths to commercial opportunities (UNCTAD, 2021a). There are several examples of institutions and programmes to conduct technological foresight and assessments. For example, APEC has its technology foresight center,[13] Brazil is home to the Center for Strategic Studies and Management,[14] the European Union maintains a distributed Competence Centre on Foresight within its Joint Research Centre,[15] and Peru has established a special program of technology foresight.[16] Technology assessments can also contribute to shaping public and political opinions on the social aspects of science and technology, including potential risks and opportunities, while helping policymakers identify effective, pragmatic and sustainable policy options. Newer types of technological assessments build on a broader range of inputs and can catalyse social, political, and inter-institutional debates on the pros, cons, and associated uncertainties across alternative directions.[17]

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[13] http://www.apecctf.org/

[14] https://www.cgee.org.br/

[15] https://ec.europa.eu/jrc/communities/en/node/2/article/ec-competence-centre-foresight

[16] https://portal.concytec.gob.pe/index.php/programas-especiales-de-soporte-de-cti/programa-especial-de-prospectiva-y-vigilancia-tecnologica

[17] For example, in 2021, UNCTAD launched the project "Technology assessment in the energy and agricultural sectors in Africa to accelerate progress on Science, Technology and Innovation," aiming to build capacity in three selected African countries to carry out technology assessments considering how new technologies contribute to solving social problems such as those specific to women and girls or that affect them particularly. The project will also investigate how technologies applied within the agricultural and energy sectors can support improved

5. Fostering multistakeholder collaboration

The government, the business sector, academia and other stakeholders should get together to drive the deployment of Industry 4.0 in the country in a coordinated way and aiming towards 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 for Industry 4.0 and coordinate its implementation.

The smooth functioning of a national innovation system is often linked to a good governance structure and involvement of actors representing businesses, academia and research, and national and regional governments. In countries with significant regional disparities, creating a multi-level governance structure can help distribute socio-economic growth at the regional level. Many countries recognize the importance of the NIS governance structure to allow government agencies to work closely together to develop technological standards (e.g. Egypt) or to introduce complex policy and legal and regulatory changes (e.g. Thailand).

An example of a multistakeholder mechanism for Industry 4.0 is the Brazilian Chamber I4.0. It was created in 2019 to bring together government actors and representatives from the industrial and academic sectors, under the coordination of the Ministries of Economy and Science, Technology and Innovation, to formulate and implement initiatives to boost industrial development in Brazil through adopting Industry 4.0 technologies, promoting increased productivity, competitiveness and economic development.[18]

6. Building international partnerships

Many developing countries can benefit from including an outward-looking dimension in their national strategies for Industry 4.0. Transnational knowledge, information exchange, and collaboration 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 help countries in Africa to develop and utilize regional value chains to promote the adoption of frontier technologies in critical areas such as transportation and logistics, fintech, potable water and sanitation, waste to energy, smart cities, affordable housing, and low-cost, high-quality health care (UNCTAD, 2021a).

There are already several good examples in this regard. Egypt considers international partnerships as key to mobilize resources and provide technical assistance on tools to vary the current policy mix and incentivize Industry 4.0 adoption at the firm level, as well as retaining and developing talent.[19] As part of its national strategy, the Dominican Republic is collaborating with Spain on industrial digitalization. This collaboration is expected to be strengthened with four training courses aimed at Dominican professionals taught by the School of Industrial Organization (EOI). The Ministry of Industry, Commerce and Tourism of Spain and the Ministry of Industry and Commerce of the Dominican Republic have also signed several agreements to promote digitalization in the industrial sector, focusing on increasing the industrial added value, the qualification of employment in the sector, and the development and deployment of digital solutions for the industry. A Joint Committee on Industry 4.0 was created to implement these measures, approve joint projects and study their evolution.[20]

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resilience to pandemics and massive short-term shocks and help the beneficiary African countries build the future better.

[18] https://camara40.com.br/

[19] Contributions from Egypt.

[20] Contributions from the Dominican Republic.

B. Fostering adoption of Industry 4.0

1. Raising awareness of businesses

Developing countries need to raise awareness about Industry 4.0 in various sectors and the positive impact of such technologies.[21] Governments should consider incentivizing businesses, especially SMEs, to recognize the importance of digital adoption and start the process of digital transformation.

To raise awareness, governments can set up meetings and activities to promote the benefits of the fourth industrial revolution. Governments can also help by promoting the industrial transformation with each relevant sector's stakeholders. For example, in 2019, several institutions in the Dominican Republic held the "Industry 4.0" Conference to promote industrial transformation as part of a technological transformation strategy of the country's industrial system.

The Government could also set demonstration initiatives in science parks, incubators, accelerators and innovation labs (UNCTAD, 2018b, 2019b). As part of these initiatives, it should encourage academia, research organizations and civil society to work closely with the private sector to deploy new products (UNCTAD, 2021a). For example, Kenya established the National University-Industry collaborations committee to harness the national industry innovation ecosystem.[22] Similarly, Belarus put in place its Republican Center for Technology Transfer (RCTT) to promote the transfer of technologies developed both in the country and abroad to ensure sustainable growth of the country's economy and increase the competitiveness of the Belarusian industry and agriculture.[23]

Government can also use science parks, innovation hubs, model factories and other similar platforms for facilitating technological and innovation learning through demonstrations projects. For example, as part of Kenya's national policy efforts, it developed a Masterplan for establishing S&T Parks. Currently, Dedan Kimathi University is constructing a Government-funded S&TP while Chuka University is constructing a second S&TP through collaboration with the Dutch Government. In Turkey, the Government established eight Model Factories to provide consultancy and training solutions for businesses to complete their lean and digital transformation.

2. Investment in Industry 4.0

An increasing number of countries worldwide are introducing policy measures and setting targets to attract technology-oriented investment to support the development and uptake of Industry 4.0 technologies. To attract technology-oriented investment, these countries should introduce dedicated policy measures and promotion and facilitation efforts. In particular, developing countries should consider formulating Industry 4.0 investment promotion strategies to put in place investment promotion and facilitation in line with this Industry 4.0 investment development plan. A good Industry 4.0 investment plan can be built by resetting priorities for investment promotion, targeting diverse investment activities and business functions, and facilitating green and digital investors (UNCTAD, 2020). These investment plans can also be part of the National Strategy for Industry 4.0.

There are several examples in this regard from CSTD member States. For instance, in Brazil, as part of Chamber 4.0, the Government established the initiative "Basket4.0" ("Cesta4.0"), which indicates industrial and technological segments of Industry 4.0 that can serve as a reference for investments and promotion of this industry in the country. Latvia has designed and implemented a "Green Channel" initiative, eliminating administrative burdens for high value-added investments. Among the priority industries are ICT, bioeconomics, Smart materials, photonics, biomedicine and Smart energy.

[21] Contribution from ESCWA.
[22] Contributions from Kenya.
[23] Contributions from Belarus.

In the Philippines, the Inclusive Innovation Industrial Strategy (i3S) also aims at removing obstacles to growth to attract investments. In South Africa, the programme Digital Advantage 2035 guides the implementation of national ICT research, development and innovation strategy and seeks to ensure more comprehensive and transparent investment monitoring. The Thai Government, as part of the Industry 4.0 Strategy (2017-2036), also aims to attract investments in future industries and services.

3. Financing the deployment of Industry 4.0

Several developing countries recognise a persistent lack of finance for R&D programmes continues to be a challenge for developing countries.[24] Better access to finance could accelerate the use, adoption and adaption of Industry 4.0. A challenge in this regard is that many areas associated with Industry 4.0 are new to the firms and financial intermediaries, so there is some cautiousness from those seeking and providing finance. For example, there are difficulties in proving business cases and return of investment, and that the new emerging applications of these technologies perform according to expectation.

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 are relatively fast to introduce and flexible in design and operation. Developing countries should use these funds to support strategic goals and target particular industries, activities or technologies (UNCTAD, 2021a). For example, Bank Pembangunan, one of Malaysia's first Development Financial Institutions, has allocated RM3 billion to aid manufacturers in their quest to adopt Industry 4.0 related technologies through its Industry Digitalisation Transformation Fund (IDTF).[25] In Turkey, the KOSGEB (Small and Medium Enterprises Development Organization of Turkey) provides funds for SMEs' investment projects focusing on high added-value manufacturing products in the medium-high and high-technology sectors. Similarly, some activities could be supported by procurement programmes and financing mechanisms involving local sovereign wealth funds, pension funds, institutional investors, and guarantee instruments (UNCTAD, 2021a).

In another example, the Russian Federation is implementing a set of measures intended to support projects at any stage of their technological readiness, ranging from the concept or prototype development and startup acceleration to a fully-fledged production and scaling-up of best domestic solutions. As a result of competitive calls in 2020, Russian authorities will support grants worth RUB 2.8 bn a total of 254 innovative small-business startups developing and commercializing Russian IT solutions. A further 12 IT pilot projects were approved to receive up to RUB 750 million. An additional RUB 1 bn was allocated in grants for ten more digital technology projects. A program of subsidized loans was launched to stimulate the digital transformation of business processes. As many as 15 banks were selected for the program (with another 40 willing to participate). Encouraged by the Ministry of Digital Development, the banks compiled a loan portfolio for 25 projects, seeking RUB 34.5 bn. Nine projects have already received a go-ahead.[26]

C. Protecting workers and easing workforce transitions

The adoption of Industry 4.0 in specific sectors and countries could lead to the displacement of workers in the same or other sectors in the same or other countries. Policymakers in developing countries should be particularly attuned to rapid technological changes in global value chains, in which their countries participate and how these changes would affect their workforce.

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[24] Contribution from ESCWA.
[25] https://belanjawan2021.treasury.gov.my/manfaat/index.php/en/ind-digi-trans-en
[26] Contributions by the Government of the Russian Federation.

Some policymakers believe that a loss of jobs in traditional areas will be followed by jobs in areas associated with Industry 4.0, and recognize the need to upskill and reskill its citizens whose jobs are affected by the deployment of Industry 4.0 technologies. For example, Kenya is developing building blocks towards Industry 4.0 to make that the next-generation workforce of Kenya could seize on opportunities provided by frontier technologies. Accordingly, training and mentoring a technology-savvy workforce will require a collaborative effort between training institutions and the industry to expose the next generation STI workforce to key principles of technology development.[27]

From a labour market policy point of view, the guiding question is how to enable labour markets to cope with structural change in general and more recent phenomena such as industry 4.0. For a country at the technological frontier such as Switzerland, the following elements are of particular interest in a phase of rapid change: a) Promote a business environment conducive to growth and job creation, b) the supply of skills has to be permanently adapted to changing labour market needs, c) the adaption of skills (among those also digital skills) will naturally be an issue for young people, but more often so for older persons as well, and d) protection of workers against labour market risks has to go hand in hand with incentives and support to find new jobs.

Workers who cannot be trained or retrained, and lose their jobs, should be able to rely on stronger mechanisms of social protection (UNCTAD, 2021a). By making social transfers such as unemployment benefits, governments can reduce the risk of people falling into poverty as social protection systems support workers during labour market disruptions (Milanovic, 2016a).

There is a renewed importance of labour unions to defend workers' rights and legitimate concerns about their jobs given the increasing automation of tasks. They should play a critical role in tackling new challenges in the relationship between workers and employers in the context of Industry 4.0. Many of these challenges are related to collecting and using worker's data, calling for new rights in the digital transformation era, such as the right to defined levels of privacy at work and at home (IndustriALL Global Union, 2017). For trade unions to remain relevant, they need to strengthen and update their collective bargaining agreements to cover the impact of Industry 4.0, and devise new strategies for addressing potential adverse effects of Smart production on the well-being of workers. It can be useful to conduct studies and forecasts about the future trends and potential impact of automation on production systems and labour demand. Trade unions may also try to include isolated groups of workers, such as many workers in the gig economy.

At the same time, employers' organizations can contribute to the dialogue between different stakeholders and to the development of more targeted education and training to prepare workers for the upcoming changes and needs of the labour market. The Government should also play a role, supporting the social dialogue between employers and trade unions to deal with Industry 4.0. With policy support, regulatory and legal reforms, collective bargaining could protect vulnerable workers from precarious employment, substandard conditions and marginalization.

[27] Contribution from ESCWA

VII. International collaboration

In harnessing Industry 4.0 for inclusive development, developing countries should be able to rely on technical and financial support through international cooperation and official development assistance (ODA). International cooperation is essential for supporting developing countries in building their capacities to properly identify ways to harness Industry 4.0 aligned with national development objectives and the SDGs, formulate coherent policies, and design appropriate policy instruments to promote Industry 4.0. International cooperation is also critical for building the international institutional framework to harness Industry 4.0 technologies for the SDGs and address potential unintended consequences.

In this regard, the following areas require the attention of international cooperation.

A. Sharing knowledge and information and conducting research

Governments and other stakeholders should be aware of the benefits of Industry 4.0 and how firms can absorb the associated new technologies to bridge the productivity gap. International cooperation helps to raise awareness in developing countries through sharing knowledge and information.

For example, UNIDO provides a multi-stakeholder knowledge-sharing platform to create awareness on Industry 4.0 opportunities and challenges for pursuing inclusive and sustainable industrial development in developing countries.[28] This platform shares available tools and methods for innovation management, information on training curricula for new workforce skills requirements, methods and best practices to support SMEs digital transformation and bridging the gender digital divide, and information on new infrastructure, standards and policies that need to be developed or mainstreamed for the deployment of Industry 4.0 technologies.

Convening power is a crucial element of international cooperation to gain the widest possible range of expertise, exchange, and agreement on sustainable industrial development actions. In this regard, the CSTD acts as a forum for strategic planning, sharing lessons learned and best practices, providing foresight about critical trends in STI in key sectors of the economy, the environment and society, and drawing attention to new and emerging technologies. Other platforms and fora also help to share knowledge and information concerning Industry 4.0. For example, UNIDO co-chairs of the Global Manufacturing and Industrialisation Summit (GMIS), in cooperation with the Ministry of Energy and Industry of the United Arab Emirates, to convene advanced technology actors worldwide to pursue an inclusive and sustainable Fourth Industrial Revolution.[29]

The WSIS Forum serves as a platform for sharing national strategies, policies, laws, programmes, and initiatives concerning Industry 4.0. WSIS Stocktaking database, coordinated by ITU since 2004, has collected more than 40 ICT-related national strategies, policies, laws, programmes and initiatives that have reflected upon or contributed to the development of Industry 4.0, with some recognized as the winners or champions of the WSIS Prizes contest.[30]

The international community also helps to provide developing countries with new data and analysis of the development and impact of Industry 4.0 technologies. In this regard, UNCTAD's Technology and Innovation Reports (2018b, 2021a) explored how to harness frontier technologies such as AI and robotics for sustainable development and critically examined the possibility of these technologies to widen existing inequalities and create new ones. These Reports focus on low and middle-income developing countries and least developed countries, and the most vulnerable segments of societies

[28] https://www.unido.org/unido-industry-40
[29] Contribution from UNIDO.
[30] Contributions by ITU.

while discussing the effects on high-income countries as parts of the broader context and significant drivers of frontier technologies.

To analyse the situation of Industry 4.0 and discuss its opportunities and challenges for the Arab region, ESCWA prepared a study on the Impact of the Fourth Industrial Revolution on Development in the Arab region (2019), and the "Arab Horizon 2030: innovation Perspective for the Arab region" that identified the five most relevant emerging technologies for the Arab region[31] namely AI, IoT, Big Data, Blockchain and 3D printing.

B. Helping design policies, strategies and implement initiatives

Governments in developing countries usually encounter difficulties designing and implementing policies, strategies and initiatives concerning the development and deployment of new technologies. In this regard, the international community has assisted governments in developing Industry 4.0 to ensure that they get the benefits while avoiding the potential adverse effects of this technological change.

For example, UNIDO actively supports policy development, programmes, and initiatives in beneficiary countries concerning Industry 4.0 to ensure inclusive and sustainable industrial development. UNIDO's activities complement national strategies from developed member countries such as Germany's Industrie 4.0[32] or France Alliance du Futur[33] and developing countries including Kenya's Vision 2030[34] and India's Digital India.[35] These activities build policymakers and industry associations' awareness of new infrastructure, standards and policies that need to be developed or mainstreamed to benefit from Industry 4.0. An example is establishing multi-stakeholder knowledge-sharing platforms to mainstream Industry 4.0 opportunities and challenges for pursuing inclusive and sustainable industrial development in developing countries.[36]

ESCWA has assisted its member states in developing policies and strategies related to the 4th Industrial Revolution, such as Jordan's AI and cloud computing policies, Lebanon's AI strategy, Syria's Digital Transformation Strategy, and Palestine's AI policy and Big Data readiness assessment.[37]

UNCTAD has a programme on Science, Technology and Innovation Policy (STIP) Reviews to assist countries in aligning STI policy with their development strategies. STIP Reviews can also provide information on how governments can harness Industry 4.0 technologies in traditional sectors and for economic diversification.

Governments in developing countries have a high demand for policy advisory services concerning Industry 4.0 and related technologies such as AI. The international community should increase resources for scaling up the Industry 4.0-related advisory services provided by the UN System and other international organizations supporting developing and least developed countries.

It is also key for developing countries to be assisted in the development of policies for Industry 4.0 that will ensure that they receive the benefits (e.g. increased productivity, lower consumption of

[31] https://www.unescwa.org/publications/arab-horizon-2030-innovation-perspectives-achieving-sdgs-arab-region
[32] https://www.plattform-i40.de/IP/Navigation/EN/Home/home.html
[33] http://www.industrie-dufutur.org/
[34] https://vision2030.go.ke/
[35] https://www.digitalindia.gov.in/
[36] Contributions from UNIDO.
[37] Contributions from ESCWA.

resources, decreased costs) while avoiding potential negative impacts (e.g. e-waste, cyber security, data privacy).[38]

C. Helping building capacity

The development and deployment of Industry 4.0 require all actors of the national innovation system to build new capabilities and skills. For example, from new digital skills in the workforce to work in a data-rich environment assisted by AI to the capacity of policymakers to explore new policy instruments and good practices to support digital transformation. International cooperation supports tailored programmes that help upskilling, support digitalization, and increase capacity to develop policies and strategies for developing countries to benefit from the rapid progress of digital and convergent technologies associated with Industry 4.0.

In this regard, the international community has helped firms and people in developing countries develop digital skills and use new technologies. For example, UNIDO supports small and medium enterprises in Industry 4.0 technological learning, smart manufacturing and innovation in Azerbaijan[39] and Belarus.[40] UNIDO also support capacity building in specific technologies, such as in its project for strengthening capacity for operation and maintenance with IoT technologies for Olkaria geothermal power station complex in Kenya.[41]

Several UN entities work to build the capacity of policymakers on policy design to support the deployment of Industry 4.0. For example, ESCWA has cooperated with national entities in Morocco, Palestine, and Qatar to build policy capacity in dealing with the deployment of Big Data, AI, Blockchain, and Digital transformation.[42]

The international community should continue to advocate and support human resource development to prepare for the Industry 4.0-ready economy and society.

D. Promoting technology transfer

To enable developing countries to take advantage of Industry 4.0, the international community should pursue new innovative partnership approaches for promoting technology transfer, addressing market, innovation systems and capabilities failures related to the uptake of new technologies and business models. There is also the need to complement the technology transfer and facilitate and promote the transfer of innovation capabilities, i.e. the ability to use a particular technology or set of technologies to generate value in the socioeconomic, material and natural context to which the technology is transferred, which involves more than the transfer of technological knowledge.

International cooperation should also help developing countries absorb frontier technologies and overcome potential challenges associated with Industry 4.0. International political dialogue and technical cooperation initiatives are essential for disseminating good practices and knowledge sharing to increase the competitiveness of national industries and insertion in GVCs.

The international community should take practical actions and implement tailored solutions based on countries' local needs and absorption capacities. International Organizations should leverage building on solutions developed within the country whenever possible, for example, through innovation hubs.

[38] Contributions from ITU
[39] https://open.unido.org/projects/AZ/projects/190347
[40] https://open.unido.org/projects/BY/projects/
[41] Contribution by UNIDO.
[42] Contributions from ESCWA.

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

Countries individually, but also through concerted international efforts, need to guide the development and deployment of Industry 4.0 to support sustainable development and leave no one behind. From the outset, it is essential to establish ethical frameworks and regulations for these technologies. UNCTAD's Technology and Innovation Report (2021a) lists 167 ethical frameworks concerning AI, done mainly by private sector firms and some academics, with inconsistencies and contradictions among them. This example shows the importance of international, multistakeholder efforts with the participation of stakeholders from developing countries.

In this regard, ITU-T Study Group 20 is working to address the standardization requirements of Internet of Things (IoT) technologies, with an initial focus on IoT applications in smart cities and communities. It is developing a series of standards and guidelines on security, privacy, trust, and identification for IoT, which offer a more comprehensive, interlinked, secure and holistic approach to manufacturing.[43] ITU has also established several ITU-T Focus Groups on Industry 4.0 technologies and their environmental impact, including on "Environmental Efficiency for Artificial Intelligence and other Emerging Technologies" (FG-AI4EE), on AI for autonomous and assisted driving (FG-AI4AD), and on Autonomous Networks (FG-AN). ITU-T Study Group 5 (SG5) is responsible for studies on methodologies for evaluating ICT effects on climate change and publishing guidelines for using ICTs in an eco-friendly way. Under its environmental mandate SG5 is also responsible for studying design methodologies to reduce ICTs and e-waste's adverse environmental effects, for example, through recycling of ICT facilities and equipment.[44]

ITU has published numerous international standards (ITU-T Recommendations) related to Industry 4.0 and associated technologies such as IoT. These standards are available for free download and use by developing countries. This focus on the availability of free standards allows developing countries to have the information needed to create and implement the infrastructure required for Industry 4.0. Additionally, ITU organizes events in different regions, which enable countries to get new knowledge. ITU also works with developing countries to bridge the standardization gap and help them be more involved in standardization activities.

At the regional level, ESCWA is analysing the legal framework for some member countries to identify the needed amendments to cope with the requirements of such technologies. These activities are a work in progress in Libya, Morocco, and Jordan.[45]

[43] Contributions by ITU.
[44] Contributions by ITU.
[45] Contributions from ESCWA.

VIII. Conclusions and recommendations

This Issues Paper has examined how developing countries could harness Industry 4.0 in manufacturing for inclusive development. Industry 4.0 in manufacturing entails Smart production, integrating and controlling production using sensors and equipment, including traditional machinery as well as robots, cobots and 3D printers, connected to digital networks supported by AI. Many firms that have adopted Smart production have increased productivity and reduced their environmental impact. The impact of these technologies on jobs has been a worry, particularly in developed countries, but empirical evidence shows that Industry 4.0 may create more jobs than replace. Reshoring, a major concern for developing countries, is also not expected to be a significant effect of Industry 4.0.

At the same time, an immediate and genuine concern is that Industry 4.0 is far from reality for most firms in developing countries, where economies are less diversified, and firms mainly use technologies of the Second Industrial Revolution. There cannot be Industry 4.0 without Industry in the first place. Developing countries need to industrialize t and before they can broadly benefit from Industry 4.0. Countries also cannot miss the windows of opportunity that Industry 4.0 offers for increasing productivity and sustainability. Therefore, developing countries need to 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 base.

In this regard, developing countries are encouraged to:

- **Foster economic diversification and manufacturing competency:** Developing countries, particularly low-income and the LDCs, should have economic diversification at the centre of their national development strategies and its implementation be supported by a whole of government approach.
- **Facilitate an enabling digital infrastructure:** Governments in developing countries should create the conditions for affordable, high-quality digital infrastructure that supports the competitiveness of the private sector. This requires mobilization of investment in ICT infrastructure, both public and private, and the creation of a regulatory environment that provides for sound competition in the telecommunications sector.
- **Develop National Strategies for Industry 4.0:** Governments should prepare and launch a national strategy and program or initiatives for the most relevant 4IR technologies for the country. The strategy should articulate and unified vision and deep understanding of measures needed to harness Industry 4.0 effectively. The Strategy should clearly define the direction of diffusion of Industry 4.0 within the economy, define priorities, clearly identify actions for future development and the results to be achieved.
- **Foster multistakeholder collaboration to create Industry 4.0 ecosystem:** Create institutional spaces or mechanisms that bring together all the relevant partners to develop a common vision for Industry 4.0 and coordinate its implementation. Interventions should enable an Industry 4.0 innovation ecosystem to emerge by linking academia and the private sector, including manufacturing and the digital/ICT sector. This ecosystem should be conducive to the development of a quality infrastructure for Industry 4.0. All stakeholders should collaborate closely. Inputs from private sectors and labour unions can very well assist government sectors in launching effective policies and measures. Meanwhile, policy implementation requires active cooperation from the private sector and labour unions.
- **Conduct foresight exercises:** Policymakers should consider conducting foresight exercises and bringing together key agents of change and sources of knowledge to explore possible

scenarios and develop strategic visions and intelligence to shape the future. These assessments should pay particular attention to how the diffusion of Industry 4.0 can affect different sectors and impact men and women differently. Countries should consider creating or reinforcing their national capacities in technological assessment and foresight to help their policymakers identify and exploit the potential of Industry 4.0 for sustainable development.

- **Build workforce skills for Industry 4.0:** Governments should promote initiatives to qualify and retrain the workforce and promote the Industry 4.0 technologies in production chains. They should undertake skills assessments in the manufacturing sector to determine the existing and required skills and skills shortages and develop specific and comprehensive strategies to close the identified gaps. Training and retraining should pay particular attention to the different impacts of automation on male and female workers. In this context, the role of labour unions would be significant in supporting training processes and enabling new skills to meet the needs of industry 4.0.
- **Raise awareness of the private sector:** To help developing countries benefit from the technologies that come with Industry 4.0, Governments can set up meetings and activities to promote the benefits of the fourth industrial revolution. These activities should build awareness of the modernisation and skills needed in production and how these are not an expensive extra cost but necessary for competitiveness.
- **Promote technological up-gradation in manufacturing:** Governments can also help by promoting the industrial transformation within this sector stakeholders. Governments could support good-practice sharing, training in digitalisation and new opportunities in solving business problems more effectively. They could promote the development of cooperation platforms that help promote digital solutions in companies' business processes, providing consultations and offering support tools.
- **Foster innovation in Industry 4.0 technologies:** Provide incentives for the private sector, including SMEs, and entrepreneurs to use and develop applications using Industry 4.0 technologies, including facilitating the acquisition of hardware, software and tools needed for Industry 4.0 solution. Policy instruments should aim at creating an enabling environment for the emergence of markets for Industry 4.0 solutions. They could encourage the development of new projects through competitions or financing, for example.
- **Build international partnerships:** International partnerships are crucial to mobilizing resources and providing technical assistance on policy and effective policy mix, incentivising Industry 4.0 adoption at the firm level, and retaining and developing talent. International collaborative projects on digital technologies are most relevant for the development of industry 4.0 technologies. They may play a decisive role in boosting the acquisition and assimilation of new knowledge, systems and solutions. In this context, demonstration projects involving companies showing technological maturity may be a very effective tool in paving the way for capacity building.

To support developing countries in harnessing Industry 4.0 for inclusive development, the international community could consider the following recommendations:

- **Collect and share success stories**: Collect success stories, including successful business cases, demonstrating the impact of Industry 4.0 technologies on inclusive and sustainable development. In particular, the international community should disseminate examples and information that help guide how women and girls and those in marginalized communities can benefit from 4.0 Technologies. The CSTD can play a pivotal role in disseminating knowledge and best practices, establishing partnerships and sharing knowledge on success stories in various development contexts for the benefit of all Member States.

- **Exchange of knowledge and experiences**: Facilitate the exchange of knowledge, experience, success stories, research and best practices with leading innovators, policymakers and regulators in developed and developing countries. Such an exchange could be through forums or events and platforms for knowledge and experience sharing. In this regard, CSTD has a critical role in gathering and disseminating quality information about the experiences of other countries.
- **Help design and implement national policies, strategies and programmes related to Industry 4.0**: The international community should support governments in formulating national strategies and programmes for Industry 4.0 technologies. It should help guide how to prioritize investments in STI capacity building and technology development and adaptation that address the challenges and tap into the opportunities afforded by frontier technologies such as Big Data, Al, Blockchain, Robotics, loT, Cloud computing, 3-D printing while continuing to master existing technologies. Technical assistance in this regard should make a systematic effort to involve a broad range of stakeholders to benefit from Industry 4.0 without creating unintended and adverse socio-economic effects and negative environmental externalities.
- **Promote infrastructure development**: The international community should support national infrastructure development that allows the deployment of Industry 4.0 technologies in production processes, such as digital infrastructure.
- **Pilot programmes**: The international community should support developing countries in designing and implementing pilot programs and initiatives to apply Industry 4.0 in priority sectors.
- **Scale-up capacity building activities**: Contribute to capacity building activities at national and regional levels on Industry 4.0 technologies, including creating online and hybrid training programs for professionals and the general public.
- **Network**: Support the participation of actors of the innovation system of the Member countries in international networks and programmes to build their capacity in innovation for Industry 4.0.
- **Knowledge and technology transfer**: Promote the knowledge and technology transfer between developed and developing countries on Industry 4.0 technologies. At the same time, encourage South-South cooperation to exchange knowledge and best practices. Support could come in the form of knowledge exchange and transfer, R&D projects, and business matching and joint ventures. Integration into international networks such as digital innovation hubs in Europe could contribute to the digitalisation of firms in developing countries.
- **Create joint programmes**: The international community could also help identify markets or market segments with greater demand for joint technological development. These joint programmes can help facilitate technological and commercial exchanges, especially with leading countries in these technologies.
- **Increase investment in STEM education:** Developed countries should consider increasing their investment in STEM education in developing countries through targeted programmes

(e.g. supporting girls' STEM[46] education). Alternatively, developed countries can facilitate STEM training of students from developing countries by supporting exchange or visiting programmes hosted by the universities in developed countries.

- **Technological upgrading**: Support upgrading digital and non-digital industries to increase high technology production and exports. Assist in benchmarking domestic industry firms against international firms that achieved the transformation of Industry 4.0.
- **Ethical frameworks and guidelines**: Strengthen international cooperation to develop ethical frameworks and guidelines for the adoption of 4IR technologies. Innovation management standards have great potential to help developing countries and economies in transition to leapfrog into Industry 4.0. These guiding frameworks would be relevant for all types of organizations, including SMEs.

46 https://www.usaid.gov/what-we-do/gender-equality-and-womens-empowerment/addressing-gender-programming/promoting-gender

Annex A – Experience of CSTD members with Industry 4.0

This Annex compiles and presents national strategies, laws, programmes and initiatives related to Industry 4.0 of selected CSTD member States. It also presents information regarding significant sectors and actors of the nations innovation ecosystems for Industry 4.0. The information is based on contributions from Governments in response to a questionnaire sent to all CSTD member States by UNCTAD in July 2021.

A. Belarus[47]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

The state body responsible for the organization and implementation of the digital transformation of the national economy is the Ministry of Communications and Informatization of the Republic of Belarus. Regulation of the processes of implementation of elements of Industry 4.0 at the sectoral level is carried out by ministries and departments - the Ministry of Industry, concerns Belneftekhim, Bellegprom, Belgospischeprom, etc.

The most important document implemented in the last five years was the state program for the development of the digital economy and information society for 2016-2020 (approved by the Resolution of the Council of Ministers of the Republic of Belarus of March 23, 2016 No. 235), aimed at "ensuring the development of information and communication technologies and their effective application in all spheres and industries."

To ensure favourable conditions for the development of the IT industry and the formation of competitive advantages of Belarus in the creation of the digital economy, the Decree of the President of the Republic of Belarus of December 21, 2017 No. 8 "On the Development of the Digital Economy" was adopted.

In the current fifth anniversary, the state program "Digital Development of Belarus" for 2021-2025 is being implemented (approved by the Resolution of the Council of Ministers of the Republic of Belarus of February 2, 2021 No. 66), the purpose of which is to ensure the introduction of information and communication and advanced production technologies in the national economy and the sphere of society. Among the tasks of the program:

- development of digital economy tools in various sectors of the national economy, providing for the use of advanced production technologies in production and processes of foreign economic activity, the formation of the necessary conditions for maintaining and increasing the competitiveness of Belarusian enterprises in the world market;
- increasing the comfort and safety of the population through the creation and implementation of smart city technologies, including systems for remote monitoring and accounting of the housing stock, energy consumption, the state of the environment, video analytics and others.

The National Academy of Sciences of Belarus is the custodian of the state program "Digital Development of Belarus" for 2021-2025. Within the framework of this program, the NAS of Belarus participates in the implementation of the following activities:

- Creation of an integrated system of digital cataloguing of goods (products) of the Republic of Belarus for the formation of a single market of the member states of the Eurasian Economic Union (IS "National Catalog of Goods of Belarus") (event on scientific support);

[47] Contribution of the Government of Belarus.

- Implementation of the complex project "Smart Cities of Belarus". Creation of a typical regional state digital platform "Smart City (Region)" (scientific support event).

Scientists of the National Academy of Sciences of Belarus, together with representatives of interested government bodies and other organizations, developed the Strategy "Science and Technology: 2018-2040" (hereinafter referred to as the Strategy), approved by the Resolution of the Presidium of the National Academy of Sciences of Belarus on 26.02.2018 No. 17. The main provisions of the Strategy were approved by the II Congress of Scientists of the Republic of Belarus, taking into account the provisions of the report of the President of the Republic of Belarus A.G. Lukashenko, speeches of delegates, proposals and recommendations of the sections of the Congress.

The purpose of the Strategy is to determine the priorities for the long-term development of science and technology, a set of tools and mechanisms for improving the scientific and technical sphere aimed at high growth rates and increasing the competitiveness of the national economy, its integration into the world innovation space, while ensuring national security and sovereignty.

The strategy defines the key features of the future intellectual economy and the new contours of its production system; basic foundations, goals, objectives and priorities for the development of the scientific and technological sphere; the main directions of state policy in science and innovation and tools to stimulate the scientific and technological development of the national economy for the period up to 2040; expected results of the implementation of the Strategy. The strategy is the basis for the development of forward-looking and policy documents for the medium and long term.

In accordance with the Strategy, it is planned to form a model "Intellectual Belarus", which includes three key elements:

1) Full-scale introduction of digital technologies that form the technological core of the intellectual economy. Core components: powerful centralized and distributed computing resources (super- and quantum computers; cloud and edge computing (Cloud and Edge Computing)); software based on artificial intelligence systems and involving machine learning; network resources of a new generation that combine big data (Big Data) and the principles of building neural networks. Creation of a nationwide cluster of IT companies, development and implementation of software and hardware complexes, the formation of a nationwide network that unites government bodies, business entities and specific consumers - together ensure the implementation of the concept of Belarus-IT-country (abbreviated name of the element: IT-country).
2) A developed neo-industrial complex (production of goods, works, services) that meets the challenges of the fourth industrial revolution and is built on the basis of the latest "technological package" (nano-, bio-, IT and additive technologies, composite materials with specified properties). The main characteristics of the complex: the widespread use of artificial intelligence systems; widespread robotization and the use of sensors; the introduction of technologies of the IoT and Industrial IoT; supercomputer processing of big data in order to optimize production processes and market turnover, intellectualization of transport and logistics systems. An important component of the neo-industrial complex is "smart energy" (abbreviated: New Industry 2040).
3) A highly intelligent society in which the needs of each person are harmonized with the needs of the entire society to maximize public goods.

The main direction is the formation of the Industry 4.0 platform. It involves the transition from centralized to decentralized digital production, informatization of assembling and moving components under control and the communication of machines with each other. Digitalization will make it possible to make significant improvements in production processes, design and development work, the use of raw materials and materials, as well as in the processes of supply chain management and in the regulation of the product life cycle, to obtain a wide range of products in the required volumes, while maintaining the efficiency of mass production and the flexibility of pilot production.

Intensive informatization will lead to the formation of new digital markets and smart platforms. In particular, the "New Industry 2040" complex will be formed in the industry.

The most important components that must be created in Belarus for the implementation of the element "NewIndustry 2040":

- a set of standards and solutions for network architecture;
- algorithms and tools for managing complex systems;
- a full-scale broadband Internet network integrated into the world's network resources;
- an integrated system of security and protection against external influences/access, as well as identification methods;
- creation of national standards, ensuring metrological traceability of new technologies, automation of metrology and its integration into production processes;
- a system of personnel training for the neo-industrial complex based on continuous professional development, including new approaches in the organization and planning of labour;
- a new regulatory legal framework for creating and developing production networks and integrated structures based on IT technologies.

In parallel, interactions and constructive exchange of experience of Belarusian scientists and practitioners with countries implementing initiatives like Industry 4.0 should be developed.

Priority technical and technological areas of "New Industry 2040":

- network technologies and technologies of radio frequency identification based on the industrial Internet and the Internet of Things;
- works and services based on supercomputers and cloud technologies;
- digital production technologies, including additive ones;
- mechatronic systems and technologies, robotic complexes with intelligent control systems;
- creation of a nationwide network of big data, software and supercomputers to ensure end-to-end interaction of enterprises of the real sector, as well as systems for the identification and traceability of goods;
- serial production of electric vehicles, including unmanned vehicles, and components to it (electric drives, batteries, supercapacitors and equipment for their charging);
- accelerated development of photonics (optics, laser technology, thermal imaging equipment, other equipment, including dual-use);
- in the field of microelectronics - production of matrices for information processing systems of spacecraft, production of semiconductor devices of powerful power and high-voltage electronics, high-frequency chips and microsystems;

- in instrumentation - the creation of production of optoelectronic equipment on the basis of thermal imaging, laser systems with the use of electron-optical transducers and high-frequency optical components; semiconductor generators and induction plants for heating metal for plastic deformation and heat treatment;
- production of new structural materials for mechanical engineering, construction, medicine (carbon fiber, cermets, metal plastics, growing crystals for microelectronics, etc.);
- combination of traditional design and production technologies with the principles of the formation of living organisms and natural objects.

The implementation of the Strategy will make it possible to form high-tech sectors of the national economy based on the production of V and VI technological structures, and to bring the structure of the economy of the Republic of Belarus closer to the structure of the economy of developed countries in terms of the share of higher structures.

Key sectors and actors of the innovation ecosystem for Industry 4.0

One of the key participants of the national innovation ecosystem associated with Industry 4.0 is the Republican Center for Technology Transfer (RCTT), whose goal is to promote the transfer of technologies developed both in the republic and abroad to ensure sustainable growth of the country's economy and increase the competitiveness of the Belarusian industry and agriculture, methodological guidance of technology transfer centers in the republic.

Since March 2015, RCTT has been the coordinator of the project in the Republic of Belarus "Creation of the Belarusian Business Innovation Center of the European Network for Support of Technology Transfer, Entrepreneurship Development and Establishment of Partnerships in the Field of Scientific Research" ("Creation of the Cooperation Business Centre "Enterprise Europe Network Belarus" - BCC "EEN Belarus"). The purpose of the WCC project "EEN Belarus" is to promote technology transfer, business cooperation and the establishment of partnerships in scientific research among small and medium-sized enterprises and scientific organizations of Belarus and the European Union, aimed at increasing their competitiveness.

B. Brazil[48]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

The Brazilian Chamber of Industry 4.0 brings together government, academia and the business sector to drive digital transformation in the country in a coordinated way. The Action Plan 2019-2022 of the Brazilian Chamber of Industry 4.0 established initiatives by its four working groups: (i) Technological Development and Innovation; (ii) Human Capital; (iii) Productive Chains and Development of Suppliers; and (iv) Regulation, Technical Standardization and Infrastructure.

The implementation of the Action Plan 2019-2022 achieved already important results for the productive sector in Brazil, such as:

- Modernization of the labour regulation, related to safety at work in production equipment, facilitating the interaction human-machine for the Industry 4.0;
- Monitoring of the General Law of Personal Data Protection, with legal provisions on data protection and granting of telecommunication services, and elaboration of a handbook to advise enterprises on how to apply the law;
- Establishment of the Center for the 4th Industrial Revolution, affiliated to the World Economy Forum;
- Constitution of "Basket4.0" ("Cesta4.0"), which indicates industrial and technological segments of Industry 4.0 that can serve as a reference for investments and promotion of this industry of Brazil;
- Creation of the digital platform Mapping 4.0 (Mapeamento 4.0), in which public and private institutions register their initiatives of Industry 4.0;
- Identification of soft skills capacities to instructors, teachers, professors and students that work with technologies and processes of Industry 4.0;
- Offer of courses of Industry 4.0 on digital platforms with Distance Learning methods;
- Support to the initiative "Future Factories" ("Fábricas do Futuro"), which fosters testbeds for Brazilian companies and institutions create real environments to test innovative solutions of Industry 4.0;
- Creation of the Program NAGI Digital, which constitutes a support network to the innovation management, to improve methodologies with a focus on digital transformation;
- Creation of the Program Brazil Plus Economy 4.0, which support the development and accelerate the implementation in small and medium-sized companies of 4.0 technologies such as Internet of Things (IoT), blockchain, artificial intelligence, machine learning (machine learning) and 5G internet applications;
- Funding to companies that are entering in the Industry 4.0 ecosystem, through tools such as FINEP Inovacred 4.0, BNDES Finame Máquinas 4.0, Rota 2030, FINEP IoT, and public calls like MCTI/FINEP Tecnologias 4.0;
- Release of the Standardization 4.0 Roadmap Proposal; Release of studies related to the identification of segments or niches with greater potential for national technological development.

Key sectors and actors of the innovation ecosystem for Industry 4.0

[48] Contributions from the Governmemt of Brazil.

The key industries in Brazil with high potential to increase competitiveness with 4.0 technology are automotive, oil and gas, pharmaceutical, textile, chemical, food and beverage, agroindustry and aerospace and defense, according to a recent study released in 2020.

Brazilian ecosystem of innovation is very robust, evolving many S&T institutions, science parks, universities, firms and innovation agencies. The Brazilian Chamber of Industry 4.0 seeks to involve most of the actors.

C. Dominican Republic[49]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

In August 2021, action plan 2021-2024 of the Digital Agenda 2030 was presented and launched. This includes a list of 100 projects to be executed during the period described, taking into account the context of COVID-19. The plan's components encompass six main areas: Governance and regulatory framework, connectivity and access, digital government, education and digital capabilities, digital economy, cybersecurity and technological innovation.

In May 2021, the Ministry of Industry, Trade and MSMEs (MICM) launched the First National Strategy for the Export of Modern Services, which seeks to enhance the value chains of non-traditional sectors with great export potential. Five working groups were created with actors from the public and private sectors to carry out the actions in the short, medium and long term: statistics, logistics and transport, professional services, orange economy, information and communication technologies.

This National Strategy involves the technologies associated with Industry 4.0 as essential tools for advancing and developing the country's service exports. The strategy is supported by the action plan of the Digital Agenda 2030, which creates a synergy of joint work for the support of all the productive sectors of the Dominican Republic. Some of the initiatives with a direct impact on the diffusion of Industry 4.0 in the manufacturing sector of the country include the review of the legal and fiscal framework of the Digital Goods and Services Industry, and program for strengthening firms in the industrial sector, comprising knowledge transfer, technical assistance in business issues, strengthening of quality and transfer of technologies for the development of digital products and services.

As part of a national strategy, the Dominican Republic is collaborating with Spain in industrial digitalization. This collaboration will be strengthened with four training courses aimed at Dominican professionals that will be taught by the School of Industrial Organization (EOI).

The Ministry of Industry, Commerce and Tourism of Spain and the Ministry of Industry and Commerce of the Dominican Republic have signed several agreements to promote digitalization in the industrial sector. The memorandum of understanding includes different areas of cooperation to increase the industrial added value, the qualification of employment in the sector, the development and deployment of digital solutions for the industry. A Joint Committee on Industry 4.0 was be created to implement these measures, approve joint projects and study their evolution.

The Organic Law of the National Development Strategy 2030 and its implementing regulations 134-15 constitute the Sustainable Development plan for the Dominican Republic. Additionally, a portal has been created to monitor the country's sustainable development.

Key sectors and actors of the innovation ecosystem for Industry 4.0

The primary industries that lead innovation in the Dominican Republic are free zones, public administration, the education sector, ICTs and the creative industries (orange economy).

- According to the 2021-2024 action plan of the Digital 2030 Agenda, the main actors are:
- Ministry of Public Administration (MAP)
- National Competitiveness Council (CNC)
- Government Office of Information and Communication Technologies (OGTIC)
- Ministry of Industry, Trade and MSMEs (MICM)

[49] Contributions from the Government of the Dominican Republic.

- Ministry of the Presidency (MINPRE)
- Central Bank of the Dominican Republic (BCRD)
- Dominican Institute of Telecommunications (INDOTEL)
- Ministry of Finance
- Superintendency of Banks (SIB)
- Ministry of Economy, Planning and Development (MEPYD)
- Private Sector Telecommunications Companies
- National Statistics Office (ONE)
- Ministry of Public Health (MSP)
- General Directorate of Ethics and Government Integrity (DIGEIG)
- ProCompetencia
- ProConsumidor
- Ministry of Women
- Entities of the National Cybersecurity Council
- National Department of Investigations (DNI)
- National Institute of Transit and Land Transport
- National Police
- National Health Service (SNS)
- Ministry of Education (MINERD)
- Office of Social Policy
- Ministry of Higher Education, Science and Technology (MESCYT)
- National Institute of Public Administration (INAP)
- Ministry of Tourism (MITUR)
- Ministry of Agriculture
- Institute of Professional Technical Training (INFOTEP)
- Presidential Commission for the Promotion of Innovation
- Superintendency of Securities (SIV)
- Ministry of Foreign Affairs (MIREX)
- Universidad Auténoma de Santo Domingo (UASD)
- Ministry of Public Works (MOPC)
- PROMIPYME
- Ministry of The Interior and Police

The Dominican Institute of Telecommunications (INDOTEL) is a key pioneer of industry 4.0 innovation in the country. Regarding Industry 4.0, as addressed in various activities, it has been expressed that Industry 4.0 is a new era that gives a quantitative and qualitative leap in the organization and management of value chains. This new stage is committed to greater automation, connectivity and globalization. The interrelation between different areas, such as products, processes and business models, has penetrated the industrial world, bringing the IoT (internet of things) and the world of Big Data and Analytics.

The Technological Institute of Santo Domingo (INTEC), is one of many universities promoting and researching the benefits related to the Industry4.0, and, along with Loyola Specialized Institute for Higher Studies (IEESL), they have published a scientific investigation that considers a generic approach based on the philosophy of holonic systems and modern techniques of cyber-physical systems, as well as the use of the components of Industry 4.0, such as digital twins represented through systems at discrete events that allow monitoring and managing the desired behaviour of a production system.

D. Egypt[50]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

Egypt Vision 2030 is a national agenda that reflects the state's long-term strategic plan to achieve sustainable development principles and objectives in all areas. In its third objective, the vision outlined Egypt's ambition to achieve knowledge-based economic growth and digital transformation to increase the resilience and competitiveness of the economy, promote employment, and improve the business environment. The fourth objective acknowledged the value of innovation and scientific research as key pillars to development. Similarly, the National Structural Reform Program (NSRP) that Egypt has recently launched considers Industry 4.0 one of its main pillars. The NSRP focuses on expanding the relative weight of three leading sectors: Manufacturing, Agriculture and Communication and Information Technology (ICT).

In 2017, a High-Level Inter-ministerial Committee was formulated to elaborate Egypt's Digital Transformation Strategy. The Committee was tasked with identifying the sectors that benefit the most from science, and technological development, assessing their respective technological gaps and defining the needed interventions.

The Digital Egypt ICT 2030 strategy and the National Artificial Intelligence (AI) strategy developed by the Ministry of Communication and Information Technology (MCIT) guided the upgrade of digital connectivity by mobilizing more than USD 1.6 billion since the mid-2018s to modernize ICT infrastructure, including efforts to replace copper cables with fibre optic ones and investing in 5G infrastructure. It also addressed the regulatory frameworks (E-Payments Law no. 18/2019 and The Personal Data Protection Law in 2020) and supported the establishment of the National Center for Telecommunication Services Quality Monitoring in 2020 to provide detailed reporting on services. The National Telecom Regulatory Authority (NTRA) established a roadmap for investing in Research and Development Programs for techno-regulatory and standardization work in Industry 4.0 that aims to finance joint R&D initiatives and partnerships.

To foster digitalization in firms, the Government of Egypt (GoE) provided start-ups and other businesses with guidance and resources to develop technologies on Industry 4.0, such as labs, testing facilities and co-working spaces in six innovation clusters (Mansoura, Menoufia, Minya, Sohag, Aswan and South Valley (Qena). The Information Technology Development Agency (ITIDA), an agency under MCIT, is in the process of setting up a dedicated Industry 4.0 Competence Centre that can conduct assessments and demonstrate best use cases. NTRA launched challenges for robotics and autonomous vehicle research and has set up a Fintech Fund of Funds of approx. USD 64 million managed by the Central Bank of Egypt. Fiscal incentives of up to 10%-20% of exported value-added digital services were also introduced. The MCIT also provides a full chain of support for ICT-related firms, from seed capital to incubation services, business consultancies and networking opportunities. Some of this is directed specifically to boost Industry 4.0 technologies, electronics design, Industry 4.0 manufacturing and Internet of Things (IoT) systems. Through the initiative entitled "Our Opportunity is Digital", MCIT is also setting aside at least 10% of public digital transformation projects for SMEs and start-ups, boosting demand.

MCIT has introduced numerous initiatives to increase the availability and financing of training for basic digital skills and advanced courses on information technologies among youth. Egypt now counts with various platforms/initiatives for training in digital skills, such as "Future Work is Digital" (training for web, data, digital marketing for young people), "Next Tech Leaders" (45 advanced digital technologies

[50] Contributions from the Government of Egypt.

for students, university staff and professionals), "Mahara-Tech" (training in IT fields for young people) (MCIT/ITIDA/Information Technology Institute -ITI) and occasional private sector partners) and the Internet of Things Academy for training in IoT through Mahara-Tech platform (ITI/ASRT). Advanced training is also offered through the Applied Innovation Center that fosters R&D and skills development through international partnerships in Artificial Intelligence, the Initiative to train trainers for digital technology (managed by the National Telecommunication Institute and Huawei) and the Advanced Training Centre for automation, IoT and other Industry 4.0 technologies which offers vocational training (Siemens and MTI). A digital platform was established by MSMEDA in 2018 to facilitate information sharing on the various services (e.g. financing and training) provided to MSMEs.

Key sectors and actors of the innovation ecosystem for Industry 4.0

The strategy aims to accelerate the pace of digitalization as a vehicle for development. It seeks to increase the ICT's share of GDP, enhance Egypt's export capacities from outsourcing services, and create new job opportunities. This will be particularly manifested in the manufacturing and agricultural sectors. Automation and digital solutions will be promoted in the engineering, textiles, food, agri-business and pharmaceutical industries, in addition to agricultural applications. The digitalization of the finance and energy sectors are also highlighted as important enablers to facilitate the transition to Industry 4.0 in Egypt.

E. Iran (the Islamic Republic of)[51]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

Smartness, digitalization and sustainability are at the core of future scenarios for societies and economies. In the coming years, the world will change dramatically. Industry 4.0 is a crucial driver for these changes and will converge many advanced technologies, especially digital ones, to boost productivity and disrupt business models. Like the other developing countries, Iran understands the opportunities and great potential of industry 4.0 for achieving competitive advantages.

The five pillars of Iran policies to catch up in industry 4.0 are as following:

1. Promote faster commercialization of advanced digital and production technologies through digital hubs and accelerators.
2. Reduce demand-side shortages for products and technologies of the Industrial Revolution through encouraging big industries to launch industry 4.0 projects. Many heavy and chemical industries like steel, petrochemical and car automakers launch programs to digitize their process.
3. Upgrade skills for advanced production through organizing boot camp, startup weekends
4. Provide consulting services for digitalization via maturity models and transition roadmap
5. Establish specialized funds and accelerators for building the Industry 4.0 Innovation Ecosystem.

Key sectors and actors of the innovation ecosystem for Industry 4.0

Heavy industries like the steel industry and mega petrochemical plants are pioneers in using industry 4.0 in Iran. The transformation of these energy-intensive industries is vital for increasing their competitiveness and achieving sustainability by reducing energy and water consumption.

The key actors in Iran are the ministry of Industry, Mine and Trade, Ministry of Communications and Information Technology, Ministry of energy and vice presidency for science and technology.

[51] Contributions from the Islamic Republic of Iran.

F. Kenya[52]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

Kenya is focusing on competency-based education and training (CBET) at pre-primary, primary, secondary, TVET and university levels. Students are being trained and manpower developed to thrive in the 4IR environment whose main platforms are Cloud Computing, Artificial Intelligence (AI), Internet of Things (IoT), Blockchain, Data Science (Big Data & Analytics) and Cybersecurity. Kenya is combining and integrating physical, digital and biological spheres and re-skilling and up-skilling to realize a "human-centred revolution'.

Kenya is also promoting manufacturing by increasing foreign direct investment, reducing the cost of doing business, and improving the ease of doing business. The country is also leveraging on low hanging fruits by enhancing its global competitiveness on exports of processed agro produce.

Key sectors and actors of the innovation ecosystem for Industry 4.0

To harness the national ecosystem of innovations related to the industry, Kenya established the National University-Industry collaborations committee with the following terms of reference:

- To assist public universities set up highly influential University-Industry partnerships;
- to meet the challenges of a knowledge-based economy;
- To spearhead the development of policy issues of joint concern to Universities and Industry;
- To help define the kind of skills needed by graduates, such as academic depth and critical ability, flexibility, high-level transferable skills, problem-solving skills, communication skills and the ability to learn on job quickly;
- To ensure university facilities for production plants, workshops and laboratories generate income for universities;
- To enhance the quality and quantity of university research through grants or contract funding;
- To support initiatives for cooperation, business development and dissemination of scientific research results;
- To promote commercialization of intellectual property, including innovations.

[52] Contributions from the Government of Kenya.

G. Latvia[53]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

The following policy documents have been approved for the planning period 2021-2027 (most of them are currently available only in Latvian):

- National Development Plan of Latvia for 2021-2027;[54]
- National Industrial Policy Guidelines 2021-2027 (available only in Latvian);[55]
- Guidelines for Science, Technology Development and Innovation 2021-2027 (available only in Latvian);[56]
- Research and Innovation strategy for Smart specialisation of Latvia.[57] Latvia is planning to restructure its economy with the aim of facilitating productivity growth and export of knowledge-intensive goods and services (smart re-industrialisation). It will be focused on the following key areas:
    - Knowledge-intensive bio-economy;
    - Biomedicine, medical technologies and bio-pharmacy;
    - Smart materials, technologies and engineering systems;
    - Smart energy;
    - Information and communication technologies.
- Freedom of Information Law;[58]
- Digital Transformation Guidelines for 2021-2027 (available only in Latvian;[59] summary article in English).[60] The guidelines provide for action in five directions and cover all key aspects of the digital societal breakthrough:
    - Digital skills and education,
    - Digital security and credibility,
    - Access to telecommunications services,
    - Digital transformation of the economy (including "public administration"),
    - Information communication technology (ICT) innovation development, and commercialization, industry and science.
- The Space Strategy of Latvia 2021-2027;[61]
- Latvia Open Data Portal (available only in Latvian);[62]

Latvia has also designed and implemented several support programmes and initiatives (available only in Latvian)

- In general about digitalisation support;[63]

[53] Contributions from the Government of Latvia.
[54] https://www.pkc.gov.lv/sites/default/files/inline-files/NAP2027__ENG.pdf
[55] https://www.em.gov.lv/lv/media/4157/download
[56] http://polsis.mk.gov.lv/documents/7053
[57] https://www.izm.gov.lv/en/smart-specialisation-strategy
[58] https://likumi.lv/ta/en/en/id/50601-freedom-of-information-law
[59] https://likumi.lv/ta/id/324715-par-digitalas-transformacijas-pamatnostadnem-20212027-gadam
[60] https://www.varam.gov.lv/en/article/latvian-digital-transformation-guidelines-2021-2027-accellation-digital-capacities-future-society-and-economy
[61] https://www.izm.gov.lv/en/space-policy
[62] https://data.gov.lv/lv
[63] https://www.em.gov.lv/lv/digitalizacija

- Innovation Motivation Programme; [64]
- Business Incubators;[65]
- Start-up support programmes;[66]
- Innovation vouchers and support for attraction of highly-qualified specialists (in English);[67]
- Support for science result commercialisation;[68]
- International competitiveness development;[69]
- Green Channel (to relieve administrative burdens for high value-added investments) (in English).[70]

Key sectors and actors of the innovation ecosystem for Industry 4.0

The main industries engaged in Industry 4.0 are telecommunications, electronics, logistics, smart mobility, and biotechnology.

Several networks are involved in the Industry 4.0 innovation ecosystem. Some of the key networks are

- IT Cluster;[71]
- Latvian Information and Communication Technology Association (LIKTA);[72]
- European Digital Innovation Hubs (EDIH), Latvia will have two EDIHs;[73]
- Annual 5G Techritory – Europe's Leading 5G Ecosystem Forum.[74]

Some of the companies that are part of the innovation ecosystem are:

- “Latvian State Forests” – innovative logistics system, implementation of geospatial information technology products and services, drones and robots.
- LMT (Latvian Mobile Telephone) – introducing 5G technology and autonomy of unmanned aircraft; connecting 5G industry players to enable developing new solutions for connected and automated mobility; virtual call management platform developed for use in mobile networks, it replaces traditional, VoIP, and cloud PBXes with a single solution; SPARTA is one of the four EU projects aimed at strengthening the region's resilience and capabilities in cybersecurity; using AI to transform urban data into valuable information that ensures increased road safety and traffic optimization; powering drones with AI and sensors enhances the success of rescue missions such as search operations, forest fires, and more; the cross-border e-CMR solution will significantly ease the exchange of cargo information between countries and benefit the transit speed.[75]

[64] https://www.liaa.gov.lv/lv/programmas/inovaciju-motivacijas-programma
[65] https://www.liaa.gov.lv/lv/programmas/biznesa-inkubatori
[66] https://www.liaa.gov.lv/lv/programmas/jaunuznemumu-atbalsta-programmas
[67] https://startuplatvia.eu/innovation-voucher
[68] https://www.liaa.gov.lv/lv/programmas/atbalsts-petniecibas-rezultatu-komercializacijai
[69] https://www.liaa.gov.lv/lv/programmas/skv
[70]https://www.liaa.gov.lv/en/article/minister-economics-latvia-new-fast-track-green-channel-will-significantly-contribute-latvias-economic-breakthrough
[71] https://www.itbaltic.com/
[72] https://likta.lv/en/home-en/ and their “Platinum Mouse” award: https://likta.lv/platina-pele/
[73] https://digital-strategy.ec.europa.eu/en/activities/edihs
[74] https://www.5gtechritory.com/
[75] https://innovations.lmt.lv/solutions/

- SAF Tehnika – Accumulated experience, world-class intellectual capacity and a team of like-minded suppliers are the essential assets behind Customized Microwave SolutionsTM - our commitment to an industry-rare capability to design, develop and produce hundreds of supported, customer-tailored product variations, as well as numerous specific, user-adapted application techniques and features for our products all linked together by a feature-rich SAF Network Management System.[76]
- Conelum – a biotechnological startup using AI in microbiological testing, measuring cell clusterization. Solutions help companies in reducing risks of product recalls, saving products and reputation, becoming able to react on time, minimizing negative consequences of unlikely events of outbreaks.[77]
- MikroTik –provides hardware and software for Internet connectivity in most of the countries around the world.[78]
- Mobilly – super convenient and user-friendly billing system for mobile phones around. With the Mobilly application, you can pay for car parks, entry fees in Jurmala, taxi services, postage, purchase train and bus tickets, supplement Bite cards, purchase Helio interactive TV codes, make donations and pay for other goods and services.[79]
- Dots – strives to take a different approach by using the latest advancements in Cloud and Machine Learning to solve challenges related to efficiency, mobility and security.[80]
- Tilde – drives innovation in European language technologies, provides worldwide award-winning language technology, translation and localisation services. Tilde provides localization services, develops custom machine translation systems, and offers online terminology tools for a wide range of languages.[81]

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[76] https://www.saftehnika.com/en/about#
[77] https://www.conelum.com/about_us.html
[78] https://mikrotik.com/aboutus
[79] https://mobilly.lv/en/about-mobilly/
[80] https://www.wearedots.com/en/about-us
[81] https://www.tilde.com/

H. Peru[82]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

There are several initiatives in each sector of government, whether in transport and communications, production, energy and mines, education, health, foreign trade, agriculture, among others. The Government has also implemented several standards, strategies and programs related to Industry 4.0:

- Supreme Decree No. 015-2016-PCM approves the National Policy for the Development of Science, Technology and Technological Innovation.
- Supreme Decree No. 345-2018-PCM approves the National Competitiveness and Productivity Policy.
- Supreme Decree No. 255-2019-EF approves the National Policy of Financial Inclusion and modifies Supreme Decree No. 029-2014-EF, which creates the Multisectoral Commission for Financial Inclusion, approves the National Policy of Inclusion Financial (PNIF).
- Emergency Decree No. 006-2020 creates the National Digital Transformation System.
- Urgency Decree No. 007-2020 approves the Digital Trust Framework and Provides Measures for its Strengthening.
- Legislative Decree No. 1412, Legislative Decree approves the Digital Government Law
- Supreme Decree No. 029-2021-PCM approves the Regulation of Legislative Decree No. 1412, Legislative Decree that approves the Digital Government Law. It establishes provisions on the conditions, requirements and use of electronic technologies and media.
- National Digital Transformation Policy, whose priority objectives were presented and is currently in the approval process.
- National Artificial Intelligence Strategy, which was presented at the national level, comments were received until 4 June 2021,[83] and is now in the review process for approval by Supreme Decree.[84]
- National Data Governance Strategy, which was presented at the national level[85] and is now in the process of receiving comments from the public until 17 September 2021 to later analyze, incorporate and carry out a final review for approval by Supreme Decree.[86]
- National Strategy for Security and Digital Trust, which was presented at the national level and is now in the review process for approval by Supreme Decree.[87]
- National Digital Talent Strategy, which has started its design with a committee of experts.[88]

The 2021-2030 National Science, Technology and Innovation Policy is also being completed, including the mechanisms for adopting and developing 4.0 technologies.

[82] Contributions of the Government of Peru.
[83] https://www.gob.pe/13517-participar-de-la-estrategia-nacional-de-inteligencia-artificial
[84] https://www.gob.pe/institucion/pcm/informes-publicaciones/1929011-estrategia-nacional-de-inteligencia-artificial
[85] https://www.gob.pe/institucion/pcm/informes-publicaciones/2046259-documento-de trabajo-para-la-Estrategia-nacional-de- government-of-data
[86] https://www.gob.pe/14331
[87] https://www.gob.pe/institucion/pcm/informes-publicaciones/1998221-estrategia-nacional-de-seguridad-y-confianza-digital
[88] https://www.gob.pe/institucion/pcm/noticias/514817-pcm-inicia-diseno-de-la-estrategia -national-digital-talent-as-part-of-the-drive-for-digital-citizenship-in-the-country

The Government of Peru has launched an initiative in 2019 within the framework of the Inter-American Commission on Science and Technology (COMCYT) of the Organization of American States (OAS), called PROSPECTA AMERICAS, to promote the use of transformative technologies 4.0. The initiative includes the promotion of prospective studies and technological surveillance on Industry 4., the infrastructure development of centres of excellence of continental scope in the different countries of America, specialized in each of the transformative technologies 4.0, and high-level training of researchers specialized in these 4.0 technologies using the existing infrastructure and those that are being created within the framework of this initiative.

Key sectors and actors of the innovation ecosystem for Industry 4.0

The key industries for Peru in the use of 4.0 technologies are manufacturing, agribusiness, mining, banking and finance, commerce and telecommunications.

The key actors are the universities (National University of Engineering - UNI, National University of San Marcos - UNMSM, Universidad Peruana Cayetano Heredia - UPCH, Pontificia Universidad Católica del Perú - PUCP, Universidad Nacional Agraria La Molina - UNALM, among others), business groups (Grupo Breca, Intercorp and Belcorp, etc.) and public entities specialized in innovation and technological development: the network of Productive Innovation and Technology Transfer Centers (CITE), the ProInnovate and ProCiencia programs and the National Science Council, Technology and Technological Innovation (CONCYTEC).

The public programs described are essential in the development and promotion of Industry 4.0. For example, the ProInnovate Program is a strategic actor of the government to strengthen specific actions concerning business innovation. Its mission is related to the objective of promoting HRT-Industry 4.0 in the medium and long term: "We manage funds for the generation of innovative projects, selecting, co-financing and technically accompanying those with the greatest potential, promoting productive development and strengthening the actors of the national business innovation system, which will be reflected in increasing business competitiveness and productivity in the country".

Similarly, the ProCiencia Program captures, manages, administers, and channels resources from national and foreign sources destined for the country's National System of Science, Technology and Innovation activities.

At the same time, universities generate large spaces for development to industry 4.0, taking into account their experience and infrastructure in terms of highly specialized major laboratory equipment, they are managing to carry out Innovation + Development + Research work. Among them are the Center for Innovation and Entrepreneurial Development (CIDE) of the Pontificia Universidad Católica del Perú, Universidad Nacional Mayor de San Marcos (Incubator 1551), USIL Ventures, accelerator of the Universidad San Ignacio de Loyola (USIL) and STARTUP UNI, Technology-based Business Incubator of the National University of Engineering.

I. Philippines[89]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

President Rodrigo Duterte has signed a law that would harness innovation efforts to help the poor and the marginalized and enable micro, small and medium enterprises (MSMEs) to be part of the domestic and global supply chain. The Philippine Innovation Act or Republic Act 11293 mandates the government to promote local innovation through relevant provisions, which will push the country towards more significant progress. Enabling the country's MSMEs with skills and technology to sustain their business also means propelling the nation to rise with and above the neighbouring countries in Southeast Asia.

Another related law is the Innovative Startup Act or Republic Act 11377, which aims to create initiatives that will provide benefits and incentives to startups and startup enablers in the country. Some of its provisions include full or partial subsidy on the use of facilities, office space, and equipment/services provided by government or private enterprises and institutions, and grants for research, development, training, and expansion projects.

The Department of Trade and Industry (DTI), a consistent government partner of the DOST in innovative programs and activities, is also at the forefront of the Inclusive Innovation Industrial Strategy (i3S). In 2017, the government upgraded the Comprehensive National Industrial Strategy (CNIS) framework and released the Inclusive, Innovation-led Industrial Strategy (i3s, "i-cube"). It retains goals in the CNIS framework, i.e., strengthening domestic supply chains, deepening participation in GVCs, and removing obstacles to growth to attract investments. But building an inclusive innovation ecosystem is listed as an additional goal, underscoring the importance of innovation in the industrial strategy and ultimately in transforming the economy, especially as we move towards Industry 4.0. Accordingly, the CNIS framework was revised, adding Industry 4.0 as one of the external factors affecting industry growth. The fourth industrial revolution will pose new challenges and opportunities, and to take part and survive, the Philippines must build an innovative ecosystem. Hence, the government has put innovation at the heart of the industrial strategy.

The Department of Science and Technology (DOST) leads different initiatives to push forward the country's transition into Industry 4.0. The DOST, through its attached agency, the Advanced Science and Technology Institute (DOST-ASTI), conducts various programs and projects that are aligned with the national priorities and R&D agenda. One of the pillars of AmBisyon Natin 2040, Kaunlaran, is focused on increasing potential growth. In support of this, one of the outcomes identified in the Philippine Development Plan 2017-2022 to address the country's potential growth is to build the foundation for a globally competitive knowledge economy where accelerated technology adoption and stimulated innovation are at the forefront.

This is an opportune time to embrace what Industry 4.0 has to offer. The DOST-ASTI is not lagging behind its counterparts in Asia and the Pacific in terms of its efforts in having critical S&T infrastructures and undertaking R&D in ICT and Electronics that would effect change in our society. The three flagship programs of the DOST-ASTI below are crucial to drive and spearhead the S&T sector towards Industry 4.0:

a. Emerging Research and Applications (ERA)
b. Environment for Extreme Computing Performance, Networks and Data (EXPAND)
c. Intelligent Systems Innovation for the Philippines (ISIP)

[89] Contributions from the Government of the Philippines.

Other DOST initiatives in support of Industry 4.0 include, but are not limited to, the following:

- Launching of the DOST Artificial Intelligence Programs and Technologies: Al for Better Normal Development of capability-building efforts like Learning at Scale program, AlPinas, and SPARTA since 2016 to increase the country's competitiveness and ensure the maximum economic and social benefits of Al DOST's implementation of programs and initiatives to capacitate and upskill MSMEs in the industry, researchers, and other communities.
- Small Enterprise Technology Upgrading Program (SETUP) — a nationwide strategy to encourage and assist SMEs to adopt technological innovations to improve their operations and thus boost their productivity and competitiveness. SETUP provides micro, small and medium enterprises with equipment and technical assistance to enable MSMEs to increase sales and production, streamline and improve overall company operations, upgrade the quality of products and services, conform to national and _ international standards of excellence, and be competitive in their respective fields. The DOST is transitioning to SETUP 2.0, to help the MSMEs in digitalization and automation aspects. The DOST is enhancing the implementation of SETUP to align with industry 4.0.
- Science for Change Program (S4CP) - was created to accelerate STI in the country to keep up with the developments wherein technology and innovation are game-changers. Through the Science for Change Program (S4CP), the DOST can significantly accelerate STI in the country and create a massive increase in investment in S&T Human Resource Development and R&D.
- Niche Centers in the Regions (NICER) for R&D — establishes R&D centers in the regions to promote regional development.
- R&D Leadership (RDLead) Program — engages R&D experts to lead in strengthening the research capabilities of the Higher Education Institutions (HEIs) and Research Development Institutions (RDIs).
- Collaborative Research and Development to Leverage Philippine Economy (CRADLE) Program — creates synergistic academe-industry relationship to invigorate Philippines R&D.
- Business Innovation through S&T (BIST) Program — facilitates the acquisition of strategic and relevant technologies by Filipino companies to support R&D activities.

Below is a list of other different policies, laws, programmes and initiatives in the Philippines that are related to Industry 4.0:

- Advancing R&D
    - Republic Act (RA) 11035 An Act institutionalizing the Balik Scientist Program
    - Harmonized National R&D Agenda of DOST
    - RA 10055 Technology Transfer Act of 2009
    - Intellectual Property Act
- Connectivity
    - RA 10844 DICT Act of 2015 — ICT Development Agend
    - National Broadband Pla
    - RA 10173 Data Privacy Act of 2012
    - National Cybersecurity Plan
    - RA 10173 Data Privacy Act of 2012
    - National Cybersecurity Plan
- Industrial Policies

    - E-commerce Act AO 001 series of 2008
    - Manufacturing Resurgence Program
    - Comprehensive National Industrial Strategy (CNIS)
    - 135 (Inclusive, Innovation-led Strategy)
    - RA 11032 Ease of Doing Business and Efficient Government Service Delivery Act of 2018
    - RA 9485 Anti-Red Tape Act of 2007
- Fostering Competition
    - RA 10667 or Philippine Competition Act of 2015
- Higher Education
    - RA 10931 Universal Access to Quality Tertiary Education Act
    - RA 10647 Ladderized Education Act of 2014
    - Executive Order 330, 1996 Expanded Tertiary Education Equivalency and Accreditation

Key sectors and actors of the innovation ecosystem for Industry 4.0

The key industries of the Philippines that are pioneer Industry 4.0 innovation are:

- Smart Manufacturing;
- Tool, Die, Iron and Steel
- Additive Manufacturing
- Shipbuilding
- Transport, Logistics, Construction, Tourism
- Furniture, Garments, and Creative
- Innovation, R&D
- Energy
- Climate change
- Smart agro-food / agribusiness and health
- Aerospace
- Mining and mineral processing
- Chemicals
- Shipbuilding
- Auto and Auto Parts
- Pharmaceuticals
- Electrical and Electronics, including semiconductors

For the three (3) flagship programs of DOST-ASTI mentioned in the previous item, the identified research areas are initially identified below.

- Emerging Research and Applications (ERA)
    - Space Technology, Wireless Systems, Industrial Automation, Embedded Smart Systems, Autonomous and Intelligent, Robotics and Vehicle Technology.
- Environment for Extreme Computing Performance, Networks and Data (EXPAND)
    - Advanced Networks, High-Performance Computing, Grid and Cloud Computing, Data Management and Analytics
- Intelligent Systems Innovation for the Philippines (ISIP)

- AI in Creative Arts, Computer Vision, Natural Language, Weather Risk; Internet of Things (loT), Quantum Computing, Edge Al, Intelligent API, Blockchain for Governance.

The key actors of the ecosystem in the Philippines are the government, such as through the Department of Science and Technology (DOST), academe and education (e.g., the State Universities and Colleges, Technical Education and Skills Development Authority), industry (e.g., food micro-, small-, and medium enterprises; private electronics and manufacturing companies), financial institutions (e.g., DOST SETUP Program, start-ups, Land Bank of the Philippines, Development Bank of the Philippines), and regulators (e.g., government agencies which are the Department of Trade and Industry and the Food and Drug Administration).

The DOST also has innovation hubs as part of the key networks of the ecosystem, such as:

- DOST Food Innovation Center
- DOSTs Modular Multi-Industry Innovation Center (MMIC) or "InnoHub sa Pinas"
- DOSTs Advanced Manufacturing Center (AMCeN)
- DOSTs Advanced Mechatronics, Robotics, and Industrial Automation Laboratory (AMERIAL)
- OneSTore, OneExpert, OneLab of DOST.

J. Portugal[90]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

A National Strategy for Industry 4.0 was launched in 2017. This strategy was updated in 2019 named Portugal i4.0.[91] The strategy aims at disseminating and boosting the adoption of advanced technologies and smart production in industrial sectors. The programme attaches particular importance to the qualification of human resources in the digital technologies associated with smart technological production.

The second phase of the Portugal i4.0 Programme has been addressed to a larger number of companies (following the first phase of demonstration of advanced technologies oriented towards industrial players with some technological intensity).

Key sectors and actors of the innovation ecosystem for Industry 4.0

Industries that are pioneers include Machinery, car industry, moulds, plastics and electronics.

Public Bodies:

- IAPMEI (Agência para a Competitividade e Inovação)
- ANI (Agência Nacional de Inovação)
- Programa COMPETE 2020 (to be persued in a new programme towards 2030)

Universities:

- Faculdade de Engenharia da Universidade do Porto (FEUP)
- Instituto Superior Técnico (IST) - Universidade de Lisboa
- Universidade do Minho

Associate Laboratories:

- ARISE – Laboratório Associado de Sistemas Inteligentes (with the coordination of FEUP)

Interface Institutions:

- INESC TEC
- INEGI – Instituto de Ciência e Inovação em Engenharia Mecânica e Engenharia Industrial
- DTx Digital Transformation Colab

Business Initiatives and Associations

- COTEC – Associação Empresarial para a Inovação
- PRODUTECH – Production Technologies Association

Innovation Platform:

- Plataforma Portugal i4.0

[90] Contributons from the Government of Portugal.
[91] https://www.portugal.gov.pt/pt/gc21/comunicacao/noticia?i=20170130-mecon-industria-4

K. Russian Federation[92]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

In the Russian Federation, there are several government regulations in specific areas of Industry 4.0, including:

- The National Strategy for the Development of Artificial Intelligence until 2030, enacted by Presidential Decree No. 490 dated 10 October 2019 (hereinafter - the Strategy) and defining the goals, key areas and mechanisms for the development of artificial intelligence;
- The federal project "Artificial Intelligence," approved on 27 August 2020 by the Presidium of the Governmental Commission on the Use of Information Technologies for Improving Quality of Life and Business Environment, aiming to implement the Strategy;
- The concept for the development of regulation of relations in the field of artificial intelligence technologies and robotics until 2024, enacted by RF Government Order No. 2129-r on August 19, 2020;
- RF Government Decree No. 317 "On the Implementation of the National Technology Initiative (NTI)" dated 18 April 2016, which is a long-term interagency program of public-private partnership, seeking to promote the development of new promising market sectors based on high-tech solutions that will drive the development of the global and Russian economy within the next 10-20 years.

The NTI is focused on markets, emerging from "a new technological paradigm, which developed countries are planning to shift to in the next 10-20 years." These markets either do not exist in the world today, or are not yet mature enough. The initiative identified nine key market sectors for development: air transport, automotive transport, maritime transport, neurocommunications, medicine, food, energy, industrial production, and security.

The mechanism of Innovative Science and Technology Centers (ISTC) was introduced in 2017. Pursuant to Federal Law No. 216-FZ dated July 29, 2017 the Russian Economic Development Ministry is empowered to launch and develop ISTCs as an authorized federal executive body.

ISTCs are an effective tool for combining the efforts of science, education and business. They are designed to arrange the transfer of universities' scientific competencies into business practice, and to encourage students and researchers to develop technologies that are in demand in the market, as well as to assist technology companies and startups. The centers enjoy a special legal status for conducting scientific research and applying innovative solutions.

The leaders of Industry 4.0 in Artificial Intelligence in Russia are member companies of the Artificial Intelligence Alliance such as Sberbank of Russia, Yandex, Mail.ru Group, Gazprom Neft, MTS and RDIF.

The booming growth and spread of digital technology in recent years have significantly changed the face of key sectors of the economy and social sphere. Industry 4.0 envisions end-to-end digitalization of all physical assets and their integration into the digital ecosystem together with partners involved in the value chain. Digital technology has become a key component in almost all areas related to the pandemic. This includes vaccine development, online learning, remote working, and e-commerce.

However, given the current divide between those who have access to the Internet and those who do not, the digital gap may well become a new face of disparity. That is why the Russian government is

[92] Contributions from the Government of the Russian Federation.

making extensive efforts to provide all of the country's citizens with access to the Internet, understanding that the transition to electronic government and municipal services will contribute to improving both people's standards of living and the business environment. E-government applications reduce administrative barriers, save time, and simplify the registration of businesses and obtaining approvals and clearances of all kinds.

As set forth in the mission statement of the Russian Government, one of the priority goals of the Ministry of Digital Development in 2020 is the introduction of digital technologies and platform solutions in the fields of public administration and services, including those in the interests of broad public and small and medium-sized businesses, including individual entrepreneurs.

The activities in this area resulted in a number of initiatives, such as:

1) Superservices. Superservices are a new type of government electronic services that minimize the use of paper documents and the need to attend government offices.
2) Development of communications infrastructure
3) Unified System of Identification and Authentication (USIA). "Unified system of identification and authentication in the infrastructure, providing informational and technological interaction of information systems used for the provision of public and municipal services in electronic form" is a federal government information system, designed to provide authorized access to information in governmental and other information systems.
4) Federal Register of State and Municipal Services (Functions). The federal government information system "Federal Register of State and Municipal Services (Functions)" provides for the development of a subsystem to deliver state and municipal services, the Government Services Portal (GSP).

Industry 4.0 envisions large-scale adoption of cyber-physical systems to satisfy people's common needs in day-to-day life, at work and in leisure time. End-to-end digital technologies are not linked to a single product or area of activity, but can be applied to many industries, branches and sectors of the economy, for example, education, medicine, energy, construction, agriculture, engineering and so on, thus becoming one of the key elements of Industry 4.0.

The efforts to build an "end-to-end" digital environment have included activities in certain areas and already brought some results, in particular:

- An update was made of the federal project "Digital technologies", aimed at ensuring the technological independence of the nation, upgrading the capabilities of national research and development system for the purpose of commercialization of its results, and accelerating the technological development of Russian companies to boost the competitiveness of their products and solutions in Russian and foreign markets.
- A comprehensive methodological and financial support system was established as part of the "Digital Technologies" federal project to facilitate digital technology development and digital transformation of companies.

These efforts provide for a set of measures to assist methodologically in the development and implementation of corporate digital transformation strategies on the basis of Russian IT solutions, to spur up Russian technological startups, offer grant support to small and large developers of Russian IT solutions, as well as to co-finance the introduction of these IT solutions at domestic companies, provide venture funding to projects, and subsidize borrowing and leasing initiatives.

The set of measures is intended to support projects at any stage of their technological readiness, ranging from the concept or prototype development and startup acceleration to a fully-fledged production and scaling-up of best domestic solutions.

The competitions in 2020 gave the following results: 254 innovative small-business startups, developing and commercializing Russian IT-solutions, got the nod for grants worth RUB 2.8 bn; 12 IT pilots received approval for as many as RUB 750 million; RUB 1 bn as grants were allocated for ten more projects majoring in digital technology.

- A program of subsidized loans was initiated to stimulate digital transformation of business processes. As many as 15 banks were selected for the program (with another 40 willing to join in). Encouraged by the Ministry of Digital Development, the banks compiled a loan portfolio for 25 projects, seeking in total RUB 34.5 bn. Nine projects have already received a go-ahead.
- A methodology was devised for companies to implement measures of digital transformation. For example, an update was made on the Methodical Recommendations on Digital Transformation of state corporations and companies with state participation.
- Hi-end technological advances that require centralized applied research and development of domestic equipment and machinery make use of resources and competencies of the largest Russian state-controlled technology companies on special agreements with the Government of the Russian Federation. Roadmaps were approved to give an impetus in the development of innovations in Russia, including in the fields of “Quantum Computing”, “Quantum Communications,” “5G Mobile Networks,” “Internet of Things” and “Distributed Registry Technologies.”

While taking anti-crisis measures in 2020, the Russian government continued its efforts to put the development of Industry 4.0 in the country on a sustainable path. At the end of August, it signed a memorandum of intent with the state corporations Rosatom and Rostec to launch an end-to-end digital initiative they called New Production Technologies. The agreement was concluded in fulfillment of the federal project "Digital Technologies" of the "Digital Economy" national program. The goal of this roadmap is to ensure the transition of Russian industry to a digital platform that would incorporate both design and production in a common virtual environment. The central role in this technological loop should be played by digital tools for planning, verification, and modeling of industrial processes. It is known that the roadmap authors laid a special emphasis on "digital twin" technology, which, in fact, is an integrator of almost all end-to-end digital technologies and sub-technologies used in industrial applications across the world.

L. South Africa[93]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

The Digital Futures: South Africa's Digital Readiness for the Fourth Industrial Revolution policy with the relation to the National Development Plan (NDP) sets out the mandate on Industry 4.0 about the national policy objectives of economic growth, job creation and inequality reduction. The policy focuses on the technological developments, which are an important aspect of developing a progressive digital policy, the broad digital policy essential to upkeep social and economic transformation with the narrow advanced technologies of artificial intelligence, blockchain, drones and machine learning is problematic. The policy perspective is critical to ensure that the preconditions necessary to harness the benefits of the 4IR are achieved if the technologies are to serve developmental purposes with meaning, relative than intensify present social, economic and political inequalities.

One programme is the Digital Advantage 2035, which operates through the Council for Scientific and Industrial Research (CSIR) to provide the capacity to implement the ICT Roadmap developed by DSI in 2012. The ICT Research, Development and Innovation (RDI) Implementation Roadmap is a plan to guide the implementation of national ICT research, development and innovation strategy. The Roadmap is driven by the potential to deliver socio-economic impact and illustrates a good public and private investment in ICT R&D. Digital Advantage is intended to enable South Africa to become a significant player in the global ICT RDI arena by:

- Providing more targeted engagement with industry
- Focusing on international collaboration
- Accomplishing more comprehensive and transparent monitoring of investment
- Making an impact, such as through jobs and business creation, contribution to GDP, societal influence and positioning South Africa for strategic advantage.

The Presidential Commission on FIR presented its report in 2020. The Report is a government-wide proposed strategy that highlights key challenges, pillars and enablers for FIR in South Africa.

The Commission has made recommendations spanning such strategic areas as the country's investment in human capital; artificial intelligence; advanced manufacturing and new materials; the provision of data to enable innovation; future industries and 4IR infrastructure

In March 2017, the World Economic Forum (WEF) launched the Centre for the Fourth Industrial Revolution Network (C4IR Network), with the mission of ensuring that the fourth industrial revolution (4IR) does not just benefit a select few, but all of society. The methodology is a human-centric approach that is agile and based on rapid iteration.

The WEF's intent is for the C4IR Network to serve as:

- A space for Global Cooperation: It is dedicated to co-designing policy frameworks and governance protocols, including laws, regulations, norms and best practices that accelerate the application of science and technology in the global public interest.
- A "do-tank": Partner governments and companies will co-design and pilot these frameworks and protocols for rapid iteration and scale. The Centre is not a think-tank, but rather a "do-tank".

[93] Contributions from the Government of South Africa.

- A champion for ethics and values in technology: All policies, frameworks and regulations developed at the Centre will prioritise ethics and values

The C4IR Network has established Centres globally and has already begun its expansion into other regions through its Affiliate Centre model. A WEF 4IR affiliate center was established in South Africa hosted at the CSIR.[94]

Key sectors and actors of the innovation ecosystem for Industry 4.0

National Advisory Council on Innovation (NACI) articulates the ability to mobilise the National System of Innovation (NSI) stakeholders and provide access to local and international experts who complement limited resources. The NSI is a network of institutions and resources in the public and private sectors that develop, share, support and promote science and technology innovations, knowledge, skills, performance and learning on a national level.

A major Department of Science and Innovation (DSI) initiative, together with the National Research Foundation (NRF) is the multibillion-rand Square Kilometre Array (SKA), which is hosted in South Africa and Australia, and which extends into eight African countries. The SKA is the world's biggest telescope and also one of the biggest-ever scientific projects and multinational collaborations in the name of science. The amounts of data being collected and transmitted by the SKA means the project requires supercomputing power and Big Data management and analytics capabilities.

The DSI has focused on the Council for Scientific and Industrial Research (CSIR) to strengthen industrial policy in the country, such as the South African Affiliate Centre of the World Economic Forum for the Fourth Industrial Revolution, joining alongside China, India and Japan. The main focus is on understanding and dealing with technology governance challenges that prevent innovation and the effective deployment of technologies. The centre will be a multi-stakeholder partnership, bringing all together government, business, and other non-state actors to jointly assess technology governance challenges and to develop arrangements that can address the requirements of different stakeholders. The key portfolios include AI and Machine Learning, Internet of Things, Robotics, Smart Cities and Digital Trade.

[94] https://www.c4ir-sa.co.za/

M. Switzerland[95]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

The Federal Council is accompanying digitisation with its horizontal umbrella strategy "Digital Switzerland". The strategy comprises various fields of action (i.a. economy, research and innovation, artificial intelligence etc.) and an action plan with around 160 measures. The strategy is based on a multi-stakeholder approach and is updated regularly. In its current version, a special focus is laid on environmental issues and data policy.

There is no official strategy or program regarding Industry 4.0. Switzerland has an innovation policy that is not structured within the framework of a single comprehensive "innovation strategy" but rather in a decentralised manner and within several independent policy areas that are coordinated as needed. This gives individual actors in R&D and in the corporate world a high degree of autonomy; on the other hand, it enables precisely tailored responses to address new challenges and harness new opportunities. This "bottom-up" approach also applies in principle to Industry 4.0 as a sub-area of digitalisation.

Switzerland is focusing primarily on creating optimal framework conditions for various types of business models, including the digital economy. In connection with digitization and/or Industry 4.0, Switzerland does not provide targeted subsidies for industries and/or technologies. To fully exploit the economic potential of digitisation, Switzerland pays particular attention to the framework conditions in the following areas: Education and further education (digital skills etc.), the research environment, data protection (legal security, trust), cyber risks and efficient and secure ICT infrastructures. In addition, necessary regulatory adjustments are being tackled (e.g. Fintech) and digital government services promoted.

The private initiative Industry 2025 is the national initiative with the goal of driving forward the digital transformation in the Swiss manufacturing sector. It brings together stakeholders and deepens existing knowledge and experience, and makes them freely available. It ensures the introduction, support and embedding of Industrie 4.0 concepts in added-value networks and production companies. Industrie 2025 was founded in June 2015 by various industry associations.[96]

From a labour market policy point of view, the guiding question is how to enable labour markets to cope with structural change in general and more recent phenomena such as industry 4.0. For Switzerland, the following elements are of particular interest in a phase of rapid change:

- Promote a business environment conducive to growth and job creation. Competition is a motor for innovation and productivity growth. Labour market regulation has to enable the reallocation of workers towards the most productive firms.
- The supply of skills has to be permanently adapted to changing labour market needs. In Switzerland – with its dual apprenticeship system - the link between education and the industry is tight. The cooperation between the education and the business sector will be a cornerstone of successful skills-policies in the future.

[95] Contributions from the Government of Switzerland.
[96] www.industrie2025.ch

- The adaption of skills (among those also digital skills) will naturally be an issue for young people, but more often so for older persons as well. Preparing the adult workforce to work with new technologies will be a key focus of Swiss skills policies in the coming years.
- Protection of workers against labour market risks has to go hand in hand with incentives and support to find new jobs. Activation is central in Swiss unemployment insurance. In times of rapid structural change, activation can also help workers to move from shrinking to growing sectors.

Key sectors and actors of the innovation ecosystem for Industry 4.0

Economic actors organise themselves in numerous initiatives that deal directly or indirectly with the topic of Industry 4.0:

- Industrie 2025;[97]
- Swiss Smart Factory;[98]
- Swiss Data Alliance;[99]
- SwissCognitive;[100]
- Digitalswitzerland;[101]
- Crypto Valley;[102]
- Trust Valley;[103]

In addition to these activities, companies are pursuing their own projects. With respect to AI, they address aspects such as ethical guidelines, the responsible use of AI or similar topics in order to promote trust in products and services in which AI is used.

Most Swiss higher education institutions, ETHs, universities and universities of applied sciences are heavily involved in the subject of AI, robotics, Internet of Things, and blockchain, from a wide variety of perspectives (some examples below):

- Institute of Robotics and Intelligent Systems;[104]
- Istituto Dalle Molle di Studi sull'Intelligenza Artificiale IDSIA;[105]
- Institut de recherche IDIAP ;[106]
- Swiss Data Science Center SDSC;[107]
- Datalab – The ZHAW Data Science Laboratory;[108]
- UZH Blockchain Center;[109]
- EPFL Center for Intelligent Systems and Innovationpark.

[97] https://www.industrie2025.ch/fr/
[98] https://www.sipbb.ch/en/forschung/swiss-smart-factory/
[99] https://www.swissdataalliance.ch/
[100] https://swisscognitive.ch/
[101] https://digitalswitzerland.com/de/
[102] https://cryptovalley.swiss/
[103] https://trustvalley.swiss/en/
[104] https://www.iris.ethz.ch/
[105] https://www.idsia.ch/
[106] https://www.idiap.ch/fr
[107] https://datascience.ch/
[108] https://www.zhaw.ch/de/forschung/departementsuebergreifende-kooperationen/datalab/
[109] https://www.blockchain.uzh.ch/

N. Thailand[110]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

The National Strategy (2018-2037) is the core development strategy of Thailand. Under the plan, Thailand 4.0 initiative is implemented as a new economic model based on innovation, creativity, high-quality services, and new technology that are employed for boosting the quality of life. This Thailand 4.0 initiative is a stepping stone in the advancement of the country's development, especially through future industries and services that can be key growth engines designed to push Thailand to become a developed country. The digital industry, including data technology and artificial intelligence, is one of the 10 Thai S-curve Industries to attain the Thailand 4.0 policy.

Thailand has implemented a number of policies to harness the potential of the fourth industrial revolution known as Thailand 4.0 Policy. In the beginning, Thailand 1.0 (1961) focused on Agriculture and Handicraft. In 1982, Thailand moved to develop the Light Industry (import substitution, consuming natural resources, low-cost labour) and expanded to Heavy Industry (export-led, promoting FDI, importing hi-technology) in 1997. "Thailand 4.0" is a concept that was used in 2018. It is a visionary scheme with the aim of transforming the country into a value-based and innovation-driven economy. Thailand 4.0 is applied and implemented in conjunction with the twelfth national economic and social development plan and the 20-year national strategy, aiming at promoting an annual GDP growth rate about 5% to become a developed country.

The 20-year Industry 4.0 Strategy (2017-2036) was written by the Ministry of Industry to drive Thailand 4.0 policy under the vision of "Move toward the intelligence industrial and link to global economy". This strategy aims to promote an industrial GDP growth rate of at least 4.5 per cent per year, investment in industrial sector growth at least 10 per cent per year, export growth of at least 8 per cent per year and Total Factor Productivity (TFP) growth of at least 2 per cent per year. This is the rate of expansion that will allow Thailand to move to a high-income country by 2036, according to the goals of the national strategy.

The Ministry of Industry is responsible for the national strategy and plan concerning industrial development. The revised 2017-2021 National Industrial Development Plan sets the vision for Thai industry to be driven by innovation, eco-friendliness and global economy by 2021. The plan outlines strategies in four areas:

1) Enhance capacity and foster the growth of Thai industry by promoting the use of science, technology, innovation and digitalisation in product development and production efficiency improvement; developing skills - management, technology and innovation - of entrepreneurs, workers and all players in the value chain; encouraging value addition of domestic raw materials and effectively managing local supply to fulfil the demand of raw materials; improving product standards and inspection process to enhance industrial competitiveness and provide consumer protection; increasing efficiency of logistics and supply chain management; and elevating national target industrial clusters to ASEAN industrial clusters.
2) Strengthen an industrial ecosystem to support the transformation to Industry 4.0 by creating a conducive legal and regulatory framework for businesses; developing economic and industrial intelligence for policy setting and early warning for industrial development; designing urban planning for industrial development; and establishing and strengthening design and inspection centres for industrial products and processes.

[110] Contributions from the Government of Thailand.

3) Promote responsible production by designing compliance and enforcement mechanisms; supporting the development of eco-industrial towns; establishing integrated industrial waste management systems with the focus on waste utilization; upgrading potential industrial clusters to eco industry; promoting eco-efficiency and the creation of eco-friendly products; and advocating for environmental impact monitoring and management organisations with public engagement.
4) Improve industry-related service efficiency of government agencies by promoting ethics, good governance and anti-corruption; improving process efficiency and ensuring adequate resources and IT tools; strengthening human resource development; and striving to provide quality services.

In line with the National Strategy, the Ministry of Digital Economy and Society (MDES) has launched the Digital Economy and Society Development Plan as a framework to utilise digital technology as a key mechanism for the national economy and social development. Within this context, the Digital Economy Promotion Agency (DEPA), a government agency under MDES, has also launched the Digital Economy Promotion Master Plan, focusing on transforming traditional industry to industry 4.0 through technology development and adoption on both supply and demand sides. In particular, the agency aims to drive development in value-based industries such as high value-added hardware and software, platform economy, and creative digital content, along with helping traditional hardware and software industries to adapt themselves into the industry 4.0 era.

Key sectors and actors of the innovation ecosystem for Industry 4.0

Ten newly targeted industries were selected with a hope to serve as new and more sustainable growth engines. These ten industries are equally divided into two segments, five S-curved and five new S-curved industries. The five S-curved industries include new-generation automotive, smart electronics, affluent, medical and wellness tourism, agriculture and biotechnology, and food for the future. The new S-curved industries are nascent high-tech industries slated to become significant long-term growth drivers. The five new S-curved industries include manufacturing robotics, medical hub, aviation and logistics, biofuels and biochemicals and digital industries.

There is no specific regulatory body designated to be the key actor for the national ecosystem of Industry 4.0 innovation in Thailand as it is a national issue that requires cooperation from all stakeholders, including public sectors, private sectors, academic institutions, and research centers, to drive Thai industry towards Industry 4.0.

Currently, Thai government agencies are key actors driving Industry 4.0, but they work closely with education and private sectors to develop many important actions. The key steps can be divided into six activities as follows:

- Promote R&D investment, social adoption, and commercialization
    - Invest in R&D and technology in competent industries
    - Invest in R&D and technology, resulting in a leap in the growth
    - Invest in R&D and technology for society to promote inclusive growth and quality of life
    - Accelerate R&D and technology transfer to farmers, community enterprises and SMEs
    - Develop the Thai technology and market for innovative product
    - Promote a world-class IP system and National Quality Infrastructure
- Develop Technopreneurs

    - Enhance entrepreneurs to play a key role in innovation and technology development and co-lead direction with government, academia, etc.
    - Promote innovation, especially in design and technology development
    - Promote culture for IPR Protection
    - Facilitate start-ups and SMEs to access capital and funds
    - Provide a proper environment for districts and communities to learn and develop creative thinking
- Develop a proper environment for the promotion of science, technology, research and innovation (STRI)
    - Develop human resources with STEM (Increase HR in STEM education, enhance researcher capability, use tax incentive to attract specialists from abroad)
    - Science and technology infrastructure (Improve effective research system, promote quality infrastructure system, accelerate government ICT, support new financial tools, promote the sharing of R&D facilities, encourage and accelerate Regulatory Reform)
    - Develop public management systems (Restructure public organisations, improve government budgeting systems, launch a Technology Development Roadmap, encourage knowledge exchange)
- Attract investments in future industries and services
- Promote Eastern Economic Corridor (EEC) as a growth engine
    - Drive the country's investment in up-lifting innovation and advanced technology for the future generation
- The Industry Transformation Centre (ITC): Enhancing the productivity and capability of the industrial sector
    - ITC is an integrated service centre that aims to develop products, processes, and people of Thai industries by connecting private manufacturers and SMEs with innovation and research and creating opportunities, especially sharing knowledge on product development, business management, and innovation.
    - Currently, the ITC network consists of 23 centres across the country, with ITC in Kluaynamthai, Bangkok, as the headquarters. Among these are 11 regional industrial promotion centres.

For driving towards industry 4.0, MDES acts as the key actor providing both hard and soft infrastructures to the country. The ministry aims to enhance the available, accessible, and affordable broadband nationwide by rolling out broadband to every village nationwide. The soft infrastructure, such as the right regulatory framework, is also promoted through amending existing laws (i.e. Electronic Transactions Act and Computer Crime Act) or putting in place new act to ensure trust and confidence of both the general public and business entity (i.e. Personal Data Protection Act: PDPA).

Also, DEPA has been specifically assigned by law to focus on promoting the development of digital technology and innovation, the building of digital ecosystem through supporting the supply side such as digital providers and digital startups, and the adoption of digital technology or the digital transformation in all sectors (including industries and businesses), to achieve Thailand 4.0 goal in economic aspect. At the same time, the National Science and Technology Development Agency (NSTDA) and the National Innovation Agency (NIA) under the Ministry of Higher Education, Science, Research and Innovation are the main actors in supporting and promoting the broad-based technology and innovation development of the country.

Moreover, the private sector has been playing a part in complementing the ecosystem on both the demand side (i.e., Digital Council of Thailand (DCT)) and supply-side (i.e. the Federation of Thai Industries (FTI)).

O. Turkey[111]

National strategies, policies, laws, programmes and initiatives relating to Industry 4.0

Turkey takes its place in Industry 4.0 era by calling its perspective the "National Technology Initiative and Digital Turkey". Therefore all strategies, policies and programmes are around this perspective.

General Directorate for National Technology was established under The Republic of Turkey Ministry of Industry and Technology on 14 April 2020 to make arrangements to pave the way for technology transformation.

Some of the duties and power of the General Directorate for National Technology are:

- Contributing to the implementation of high-impact programs and projects to improve Turkey's technological competence within the scope of the National Technology Initiative;
- To carry out activities for the development of individual competencies and social awareness and culture in technology development and digital transformation of individuals and businesses in cooperation with relevant stakeholders in line with the objectives of the National Technology Initiative;
- To take measures to increase the competencies of individuals and businesses in subjects such as big data and artificial intelligence, to develop and expand smart systems based on these technologies, to implement support and incentive programs, to carry out programs and projects;
- To take the necessary measures in coordination and cooperation with the relevant public institutions and organizations for the development of digital economy applications and the growth of the ecosystem in this field to increase the economic benefit of digitalization, and to contribute to the creation of legislation; To carry out programs and projects for the development of digital economy infrastructures and applications in parallel with digital technologies and trends;
- To take the necessary measures, develop and carry out applications to ensure the development and competitiveness of the informatics and advanced technology sectors; keeping the register of businesses operating in these sectors; Harmonizing the technical regulations regarding the products of the informatics and advanced technology sectors, excluding those used in the electronic communication sector, preparing and implementing the technical legislation and the relevant standard lists, determining or having the features that will be the basis for the inspection of the products that do not have technical regulations and standards; To determine the qualifications that conformity assessment bodies and technical service organizations to be authorized within the scope of technical regulations, to assign these bodies, to temporarily suspend or cancel the assignment when necessary.

Small and Medium Enterprises Development Organization (KOSGEB) and The Scientific and Technological Research Council of Turkey (TÜBİTAK), which are organizations of The Republic of Turkey Ministry of Industry and Technology, open grant programs to support the digital transformation of SMEs.

11th National Development Plan (NDP), 2023 Industry and Technology Strategy and Smart Production Systems Technology Roadmap can be noted as main policies and strategies concerning Industry 4.0.

[111] Contributions from the Government of Turkey.

In July 2019, Turkey adopted the 11th National Development Plan (NDP) with a 5-year perspective, i.e. covering 2019-2023.

Policies and strategies of digital transformation of conventional sectors are given place to the Eleventh Development Plan of Presidency of the Republic of Turkey Presidency of Strategy and Budget. Under the "Digital Transformation" and "R&D and Innovation" sections of the strategy, policies and measures are given in the objective of boosting productivity and competitiveness in priority sectors by accelerating digital transformation and strengthen the R&D and innovation capability of the manufacturing industry to enable value-added production and to increase the capacity of innovative product development and to provide an innovation-based structure.

The 11th Development Plan sets forth Turkey's long term vision for economic and social development. It is the main roadmap for public policy, which leads all governmental institutions with regard to preparation processes of strategic and action plans. The plan lays down the main pillars of STI policies, emphasizing the need to develop the capacity to produce and use knowledge and to focus R&D and innovation activities both in academia and in the private sector that support high value-added production, particularly through an efficient R&D and innovation ecosystem. Additionally, the Plan emphasizes entrepreneurship and commercialization activities tailored for different actors in the industry (SMEs, big size enterprises etc) and the transfer of knowledge and technology (enabling socio-economic impacts of R&D results). Concerning the R&D and innovation, enhancing the capacity for R&D and innovation capabilities, increasing the value-added production and the share of high-tech sectors within both manufacturing industry and exports and ensuring a convenient environment for innovation are determined as the primary goals. To this end, R&D and innovation support systems are determined to be evolved to an integrated structure from basic research to commercialization at every phase of R&D and innovation; while the distinctive structures and characteristics of mid-high tech and high tech sectors will be favoured. In this context, priority sectors are identified as chemical industry, pharmaceuticals and medical devices, electronics, machine and electrical equipment, automotive and rail systems. Artificial intelligence, IoT, augmented reality, big data, cyber security, energy storage, advanced materials, robotics, micro-nano-electromechanical systems (MEMS/NEMS), biotechnology, quantum technologies, sensors and additive manufacturing technologies are determined as the critical technologies, where the human resources is to be further supported, infrastructures to be established and roadmaps to be developed.

Increasing the competitiveness in priority sectors and improving the R&D and innovation capacity, and developing internationally competitive and high value-added new sectors, products and brands in the critical technologies have been given utmost importance within the Plan.

Turkey has published the 2023 Industry and Technology Strategy of The Republic of Turkey Ministry of Industry and Technology. The strategy has five pillars, namely, High Technology and Innovation, Digital Transformation and Industrial Move, Entrepreneurship, Human Capital, and Infrastructure. Sub strategies (namely, Digital Transformation of the Industry, The National Artificial Intelligence Strategy, 5G and Beyond Technologies Strategy, Mobility Vehicles and Technologies Strategy, Smart Life, Health Products and Technologies Strategy, Digital Transformation of Finance and Commerce Strategy) serving this umbrella strategy have been developed and are in the process of publication and implementation.

The main purpose of the Digital Transformation of the Industry Strategy is to provide efficiency and self-efficacy to increase the competitiveness of Turkey. Targets of the strategy are as follows:

1. Establishment of the proposed governance mechanism for the industry's digital transformation program with the cooperation of the public and private sectors.

2. Completion of the development of tools that will ensure the management of the digital transformation of the industry, monitoring its performance and efficient use of resources.
3. Announcement of the digital transformation support program.
4. Completion of the infrastructure for digital transformation.
5. Gaining new skills and competencies that will enable digital transformation to the existing and emerging workforce.
6. Development of competitive products and solutions in Operational Technologies.
7. Developing competitive products and solutions in Information Technologies.
8. Creation of competitive products and solutions in Transactional Technologies.

Digital transformation in the manufacturing industry is considered critical in Turkey. Through the coordination of TÜBİTAK (the Scientific and Technological Research Council of Turkey) under the framework of the Ministry of Industry and Technology, all sectoral stakeholders have participated towards the establishment of the Smart Production Systems Technology Roadmap in 2016. In total, 29 critical products have been identified in the context of 8 critical technology areas that are determined in this roadmap, namely Big Data and Cloud Computing, Digitalization, Cybersecurity, Internet of Things, Sensor Technologies, Additive Manufacturing, Advanced Robotics, Advanced Automation and Control Technologies.

The critical products/technologies, which are identified as priority RDI themes of Smart Production Systems for Turkey, are as follows:

- Development of algorithms and applications for secure, smart and scalable end-to-end cloud service platform, which also enables and predictive maintenance of data
- Development of cyber security solutions for Industry 4.0
- Simulation, modelling and virtualization technologies for Industry 4.0
- Establishment of interoperable, secure and reliable industrial IoT digital platform and development of high added value smart service applications
- Development of Software and/or Hardware for Machine-to-Machine, Machine-to-Human, Machine-to-Infrastructure Communication
- Development of physical, chemical, biological, optic, micro-nano sensors for industrial use
- Development of smart manufacturing robots, equipment, software and executive systems which are competitive in global markets, easily accessible by SMEs
- Development of raw materials, production machines and required software and automation systems for additive manufacturing. Additive Manufacturing Machines, Additive Manufacturing Materials, Additive Manufacturing Software
- Development of smart manufacturing execution system and components, as well as required middleware technologies

Dedicated R&D and innovation supports have been provided to universities, SMEs and large industrial organizations for the development of critical technologies serving digital transformation since 2012 by TÜBİTAK.

So far, the top area based on the distribution of the total budgets of the supported projects has been “sensors, electronic circuits and microelectromechanical systems” with a share of 21% in first place. This has been followed by “communication systems” with a share of 20% and subsequently, two areas each with a share of 15% as “artificial intelligence” and “robotic-mechatronics”. The area of “data analytics” takes fifth place with a share of 10%.

The New “RDI Priority Areas (2020-2021) Study conducted by TUBITAK includes various technology intensive sub-priorities in the fields of ICT, health, food, energy, machine&manufacturing and automotive. In this context, in ICT sector, artificial intelligence, internet of things, big data and data analytics, image processing technologies, robotics, software technologies, cloud computing, broadband technologies are all considered to be priority technologies for near future; and all of which are the basis of digitalization, have been prepared along with detailed contents and technological readiness levels. 64 of the 154 RDI priority areas, approximately 42% of all “RDI Priority Areas (2020-2021)”, are the ICT and digitalization related ones.

Since 2020, TÜBİTAK has been giving priority to RDI project proposals within the evaluation phases of TÜBİTAK 1001 - Scientific and Technological Research Projects Support Program, TÜBİTAK 1501 - Industry R&D Projects Support Program and TÜBİTAK 1507 - SME R&D Start Support Program if the proposal is concerned at least one of these determined RDI Priority Areas. Projects dedicated to develop the given priority technologies and products are supported by TÜBİTAK within the scope of R&D and innovation support programs or through the Move Program within the scope of the National Technology Move by the Ministry of Industry and Technology.

Some Initiatives concerning Industry 4.0 in Turkey are:

- Model Factories: Eight Model Factories (Capability and Digital Transformation Centers), established with the Ministry of Industry and Technology initiative, provide consultancy and training solutions for businesses to complete their lean and digital transformation. New model factories are planned to be established in different areas of Turkey in the coming years. The businesses which demand services from Model Factories can benefit from financial support through the government agency KOSGEB and Development Agencies.
- Fourth Industrial Revolution Center - The Center for the Fourth Industrial Revolution (C4IR): This is a multi-stakeholder initiative that supports global collaborations and develops new policies to accelerate the benefits of science and technology. The center was launched in December 2020 by WEF, MESS, and Ministry of Industry and Technology. Briefs about the organization:
    - Maximizing the benefits of science and technology to the society
    - As of January 2020, WEF's 7th affiliated organization (Affiliate Center)
    - Main working titles; Internet of Things, Robotics, Smart Cities, Artificial Intelligence and Machine Learning
    - Active projects; Increasing the Impact of Industrial IoT in SMEs, Responsible Use of Artificial Intelligence, Human-Oriented Artificial Intelligence for Human Resources, Shaping Future Technology Control: Artificial Intelligence and Machine Learning.
- Accelerating Digital Transformation of SMEs Through IoT: MoIT is a stakeholder of the project "Accelerating digital transformation of SMEs through IoT" operated jointly by "Fourth Industrial Revolution Center" and "TÜSSİDE". The eventual aim of the project is to create a model for "building roadmap for companies". This project will be the pilot for the model and it comprehends the following steps:
    - Digital maturity assessments of SME’s
    - Matching the technology users and technology providers and creation of "use case senarios pool"
    - Accumulating and keeping the application scenarios in an industrial cloud.

- D3A Digital Transformation Assessment Tool: 'D3A Digital Transformation Evaluation Tool' was developed by Boğaziçi University - Industry 4.0 Platform. TUBITAK - TÜSSİDE (Turkish Management Science Institute) is to ensure the implementation of these assessment tools for SME's. Assessment tool focuses on SME's which corresponds to the 99 percent of Turkey's industry and this tool will provide road maps for them. Focusing on five dimensions which are organization, customer, product development, supply chain and production management, D3A aims to determine the needs of SME's and to run their digital transformation processes smoothly.

Besides the actions of the Republic of Turkey Ministry of Industry and Technology, other ministries and presidencies put effort into digital transformation.

2020 – 2023 National Cyber Security Strategy of Republic of Turkey Ministry of Transportation and Infrastructure addresses to security criteria of new generation technologies such as artificial intelligence, internet of things, blockchain, and 5G, which have a place in our lives, will take place as a priority in the cyber security plans of the near future, and "identify the areas of use of artificial intelligence and blockchain technologies for cyber security, and determine the domestic and national technologies to be developed.

2020 – 2023 National Smart Transportation Systems Strategy Document and Action Plan of Republic of Turkey Ministry of Transportation and Infrastructure states strategies that aim to create a sustainable, productive, safe, efficient, innovative, dynamic, environment-friendly intelligent transport network that creates added value and integrated with all transport modes using the latest technology while making use of national resources.

Last but not least, the Presidency of the Republic of Turkey Digital Transformation Office aims to implementation of the digital transformation ecosystem by enhancing the performance of public institutions and increasing the efficiency and quality of their services in line with the goals, policies and strategies set by the President of the Republic of Turkey.

Besides national policies are implemented by MoIT regional policies are formulated and supported by development agencies and regional support programs.

- KOSGEB (Small and Medium Enterprises Development Organization of Turkey) support programmes concerning Industry 4.0:

KOSGEB has announced two Calls for Proposals to support the digital transformation of SMEs in 2019. The first program aims to support SMEs which are developing digital technologies applicable in the industry sector. The capabilities of digital technology developers are fostered by a project-based program including 1.000.000 TRY (115.000 USD) financial support. The second program's target is SMEs that are acting in the industry sector. 1.000.000 TRY (115.000 USD) financial support is provided to industrial sector SMEs aiming to adapt digital technologies to their manufacturing and business processes.

Calls for proposals comprise eight smart digital technologies: Big Data, Internet of Things, Industrial Robot Technologies, Smart Sensor Technologies, Artificial Intelligence, Cyber Security, Smart and Flexible Manufacturing, virtual Reality / Augmented Reality. Calls for proposals were announced in 2019 and repeated in the following years. In total, 936 projects have been approved up to now.

To encourage interaction between technology developer SMEs and industrial sector SMEs:

a) Intent of purchase letter provided by an industrial SME was made obligatory for technology developer SMEs.
b) Prioritization rules were defined for industrial sector SMEs which intend to procure digital technologies from technology developer SMEs.

- Strategic Product Support Program

This program provides funds for SMEs' investment projects for manufacturing high added value products in the medium-high and high-technology sectors and increasing the production of critical products for the development of these sectors in Turkey within the scope of the Technology-Oriented Industry Move Program conducted by the Ministry of Industry and Technology (MoIT). The program offers up to 6.000.000 TL financial support with a 60 % grant ratio for projects up to 36 months aiming production of the privileged products mentioned in the calls for proposals of the Technology Oriented Industry Action Program.

Machinery equipment, software, personnel, reference sample, knowledge transfer, test, analysis, calibration, training-consultancy, design and other service procurement costs are eligible for granted projects of SMEs. MoIT publishes a list of Privileged Products and calls for specific areas through this list. In 2021, three calls (Mobility Call, Call for Structural Transformation in Production and Call for Health and Chemical Products) were put into service for investments of 722 kinds of products. Digital Transformation Call will be published by MoIT in the upcoming days. Products related to Industry 4.0 are also on the list of investments to be financially supported via these calls. Products related to Industry 4.0 in these calls:

- Big data collection platform (data validation, data integrity, data privacy, data labeling, heterogeneous data support)
- Internet of industrial things platform
- Digital Twin technologies
- Blockchain technologies (product traceability, digital product marketing, etc.) and infrastructure
- Advanced technology embedded sensor systems such as MEMS/NEMS and optical technologies to be used in internet of things applications
- Extreme-proof sensors
- Wearable technologies that can send data to the cloud and receive commands, compatible with the Internet of Things
- Cyber security technologies based on artificial intelligence and deep learning
- System-on-Chip technologies
- Robotic process automation technologies
- Autonomous/Semi-Autonomous Industrial and Service Robots
- Hybrid manufacturing systems

Key sectors and actors of the innovation ecosystem for Industry 4.0

The public sector aims to lead technological transformation with its actions. The automotive and manufacturing sectors are pioneer adopters of Industry 4.0 in order to maximize production, to minimize costs and work accidents.

Generally, corporate companies, start-ups, technology transfer offices are the key actors of the ecosystem. IBM, SAP, Microsoft, KoçSistem, Turkcell are some of the service providers for Industry 4.0

solutions. On the other hand, start-ups are mostly focusing on the digitalization of conventional machines. Since Industry 4.0 is new to the conventional sectors, there is huge potential for start-ups. ServisSoft, Hubbox, Bren Energy are some of the start-ups that could be named as promising Industry 4.0 start-ups. Technology Transfer Offices (TTOs) are another contributor to Industry 4.0. TTOs lead to the implementation of technology practices in Turkey.

One of the business association which called TÜSİAD publishes reports about Industry 4.0. Also, the association carried out TÜSİAD SD2 Digital Platform to bring together a digital solution.

In line with the importance given to the digital transformation of the industrial sector in the Eleventh Development Plan of Turkey, the issue of "digitalization in the manufacturing industry" has been among the priority themes of the government since 2019. SMEs in the industrial sector need to adapt themselves to digital technologies for the value-added production-oriented transformation of both industry and industrial workforce. The digital transformation of the industry as a strategic priority area has some fundamental gains, such as increasing resource productivity and competitiveness in general.

The Eleventh Development Plan defines automotive, chemistry, pharmaceutics and medical devices, electronics, machinery-electrical equipment, and rail system vehicles as priority sectors. In addition, the 2023 Industry and Technology Strategy aims at the digital transformation of the manufacturing industry and seeks to support this transformation with the national technology move program.

The Capability and Digital Transformation Center (Model Factory) project, which started in 2015, is one of the critical initiatives of the Ministry of Industry and Technology in this area. Model Factories, which provide applied training and consultancy services especially for SMEs, started to operate in critical industrial cities, and the number of these training centers will increase in the coming period.

Key actors both in policymaking and in the implementation of national strategies can be listed as follows: Ministry of Industry and Technology, Chambers of Industry and Commerce, NGOs, international organizations such as UNDP, and KOSGEB, which manages the government's financial support for manufacturing SMEs.

These actors are involved in all processes, from policymaking to implementation. The ministry is at the center of policy networks and manages communication between stakeholders and actors as a top-level government agency. Model Factories, which are also considered as a hub of digitalization efforts, are coordinated at the national level, and a common technical experience is gained by sharing information among them.

Industry 4.0 covers a large variety of sectors but manufacturing and ICT seem to be the pioneering sectors.

The Ministry of Industry and Technology is the most active governmental body in the administration of efforts in Industry 4.0, while R&D is mainly supported by TÜBİTAK (the Scientifical and Technological Research Council of Turkey).

The R&D is conducted in universities, the private sector, technoparks and R&D institutes. So there are a lot of actors in R&D. The key factor of success in R&D is the collaboration between these different actors. Various mechanisms are designed to increase these kinds of collaboration. TÜBİTAK SAYEM - Industrial Innovation Networks Mechanism can be counted among these efforts. In order to strengthen the industrial innovation networks in Turkey, considering the smart specialization in industrial innovation hubs; policy tools that are more target-oriented, collaborative, focused on the long-term, and directed to high value-addition are being put forward to strengthen aspects of smart specialization and inclusiveness in the local ecosystem. Through "Industrial Innovation Networks Mechanism (SAYEM)", established in 2018, private sector firms, especially those that contain an R&D

and product design centres, will form a network with other firms of the value chain of the targeted technology-based product together with end-users, technology development zones and universities.

The objectives of SAYEM can be listed as below:

- To promote the innovative network formations, leading to the creation of product road maps
- To form a network with other firms from the value chain of the targeted technology-based product, together with end-users, technology development zones and universities.
- To enhance smart specialization activities in industrial innovation hubs, including firms, especially those that contain an R&D and product design centre,

KOSGEB, as a governmental organisation, has a wide network of SMEs and field experience in supporting SMEs. These capabilities can be used to improve the Industry 4.0 concept among SMEs.

Annex B – Questions for discussion

This annex presents a set of questions for the discussion during the Intersessional Panel.

Key issues on Industry 4.0 and inclusive development

- What challenges have governments faced for promoting Industry 4.0 to contribute to national development priorities and accelerate progress towards the SDGs?

Creating the ecosystem for Industry 4.0 innovation

- How could governments better support the creation or strengthening of national and sectoral systems for Industry 4.0 innovation?
- What are the policy instruments that governments have used in this regard?
- What are the most effective ways to support the improvement of skill levels for harnessing Industry 4.0 for inclusive and sustainable development?
- What should the private sector, labour unions and other stakeholders do so that developing countries can benefit from these technologies?

Providing directionality to the sustainable and inclusive application of Industry 4.0

- What are the examples of STI policies, projects, initiatives intended to promote and give directionality to Industry 4.0 innovation to make it work for inclusive and sustainable development?

Dealing with unintended consequences

- How can STI policies ensure that potential unintended consequences of Industry 4.0 are addressed?
- What are the policy instruments that governments have used in this regard?

The role of partnerships and international and regional collaborations

- What actions can the international community, including the Commission on Science and Technology for Development, contribute to maximizing the benefits associated with Industry 4.0 and mitigate its risk?
- What are the success stories in this regard?

References

Acemoglu D and Autor D (2011a). Skills, tasks and technologies: implications for employment and earnings. *Handbook of Labor Economics*. Elsevier: 1043–1171.

Acemoglu D and Autor D (2011b). Skills, Tasks and Technologies: Implications for Employment and Earnings. *Handbook of Labor Economics, Volume 4. Amsterdam: Elsevier-North*. 1043–1171.

Akerman A, Helpman E, Itskhoki O, Muendler M-A and Redding S (2013). Sources of wage inequality. *American Economic Review*. 103(3):214–219.

Alarcón M, Martínez-García FM and Gómez de León Hijes FC (2021). Energy and maintenance management systems in the context of industry 4.0. Implementation in a real case. *Renewable and Sustainable Energy Reviews*. 142110841.

Alvarez J, Benguria F, Engbom N and Moser C (2018). Firms and the decline in earnings inequality in Brazil. *American Economic Journal: Macroeconomics*. 10(1):149–189.

Arntz M, Gregory T and Zierahn U (2016). The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis, OECD.

Auerswald PE (2010). Entry and Schumpeterian profits. *Journal of Evolutionary Economics*. 20(4):553–582.

Autor D, Dorn D and Hanson G (2015). Untangling Trade and Technology: Evidence from Local Labour Markets. *Economic Journal*. (584):621–646.

Autor DH (2013). The "task approach" to labor markets: an overview. *Journal for Labour Market Research*. 46(3):185–199.

Autor DH and Handel MJ (2013). Putting Tasks to the Test: Human Capital, Job Tasks, and Wages. *Journal of Labor Economics*. 31(S1):S59–S96.

Banga K and te Velde DW (2018). Digitalisation and the Future of Manufacturing in Africa. (accessed 28 September 2021).

Barth E, Bryson A, Davis JC and Freeman R (2016). It's where you work: increases in the dispersion of earnings across establishments and individuals in the United States. *Journal of Labor Economics*. 34(S2):S67–S97.

Berriman R and Hawksworth J (2017). Will robots steal our jobs? The potential impact of automation on the UK and other major economies. *UK Economic Outlook, PwC*. 47.

Bol T and Weeden KA (2015). Occupational Closure and Wage Inequality in Germany and the United Kingdom. *European Sociological Review*. 31(3):354–369.

Bowles J (2014). Available at https://www.bruegel.org/2014/07/chart-of-the-week-54-of-eu-jobs-at-risk-of-computerisation/ (accessed 7 September 2021).

Bradbury S, Carpizo B, Gentzel M, Horah D and Thibert J (2018). Digitally enabled reliability: Beyond predictive maintenance. Available at https://www.mckinsey.com/business-functions/operations/our-insights/digitally-enabled-reliability-beyond-predictive-maintenance (accessed 14 October 2021).

Brennen S and Kreiss D (2014). Digitalization and Digitization – Culture Digitally. (accessed 28 September 2021).

Brussevich M et al. (2018). Gender, Technology, and the Future of Work. IMF Staff Discussion Note. (accessed 11 October 2021).

Brynjolfsson E and McAfee A (2016). *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. W. W. Norton & Company. New York London.

Brzeski C and Burk I (2014). Die roboter kommen. Folgen der automatisierung für den deutschen arbeitsmarkt [The robots come. Consequences of automation for the German labour market].

Chang J-H and Huynh P (2016). The future of jobs at risk of automation. Report. (accessed 7 September 2021).

Cirera X, Comin D, Cruz M and Lee KM (2021). Firm-Level Adoption of Technologies in Senegal. Working Paper. World Bank. Washington, DC. (accessed 29 September 2021).

Cirera X, Comin D, Marcio C, Lee KM and Soares Martins-Neto A (2021). Firm-Level Technology Adoption in Vietnam. Policy Research Working Paper;No. 9567. World Bank, Washington, DC. © World Bank. (accessed 28 September 2021).

Committee for Economic Development of Australia (2015). CEDA. Available at https://www.ceda.com.au/ResearchAndPolicies/Research/Workforce-Skills/Australia-s-future-workforce (accessed 7 September 2021).

Dauth W (2014). Job polarization on local labor markets. IAB-Discussion Paper, 18/2014. (accessed 21 May 2020).

David B (2017). Computer technology and probable job destructions in Japan: An evaluation. *Journal of the Japanese and International Economies*. 43(C):77–87, Elsevier.

De Stefano V and Aloisi A (2018). European Legal framework for digital labour platforms. European Commission. Luxembourg.

Devroye D and Freeman RB (2001). Does Inequality in Skills Explain Inequality in Earnings Across Advanced Countries? Working Paper No. 8140. National Bureau of Economic Research. (accessed 31 March 2020).

Ding L and Molina JS (2020). "Forced Automation" by COVID-19? Early Trends from Current Population Survey Data. 29.

East D and Kaspar MG (2020). The impact of COVID-19 on manufacturing investments. Available at https://iap.unido.org/articles/impact-covid-19-manufacturing-investments (accessed 28 September 2021).

ESCAP (2021). ESCAP. Available at https://www.unescap.org/blog/reaping-benefits-fdi-40-and-digital-fdi-sustainable-development (accessed 6 September 2021).

ESCWA (2019). Impact of the Fourth Industrial Revolution on Development in the Arab region. (accessed 15 September 2021).

European Union (2019). A vision for the European industry until 2030 - Final report of the Industry 2030 high level industrial roundtable. Available at https://op.europa.eu/en/publication-detail/-/publication/339d0a1b-bcab-11e9-9d01-01aa75ed71a1.

Fagerberg J and Verspagen B (2021). Technological revolutions, structural change, and catching up. In: Alcorta L,, Foster-McGregor N,, Verspagen B, and Szirmai A, eds. *New Perspectives on Structural Change: Causes and Consequences of Structural Change in the Global Economy*. Oxford University Press. Oxford, New York: 131–155.

Foster-McGregor N, Nomaler O and Verspagen B (2019). Measuring the creation and adoption of new technologies using trade and patent data. *UNIDO*. 68.

Freire C (2017). *Diversification and Structural Economic Dynamics*. UNU-Merit/MGSoG dissertation series, No. 191. Boekenplan. Maastricht.

Freire C (2021). The impact of frontier technologies on inequalities across countries. Available at https://iap.unido.org/articles/impact-frontier-technologies-inequalities-across-countries (accessed 13 October 2021).

Frey CB and Osborne MA (2017). The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change*. 114254–280.

Goos M, Manning A and Salomons A (2014). Explaining job polarization: routine-biased technological change and offshoring. *American Economic Review*. 104(8):2509–2526.

Graetz G and Michaels G (2018). Robots at work. *The Review of Economics and Statistics*. 100(5):753–768.

Guadalupe M (2007). Product Market Competition, Returns to Skill, and Wage Inequality. *Journal of Labor Economics*. 25(3):439–474.

Guerriero M (2015). The impact of Internet connectivity on economic development in Sub-Saharan Africa.

Hartmann D, Guevara MR, Jara-Figueroa C, Aristarán M and Hidalgo CA (2017). Linking economic complexity, institutions, and income inequality. *World Development*. 9375–93.

Hjort J and Poulsen J (2019). The Arrival of Fast Internet and Employment in Africa. *American Economic Review*. 109(3):1032–1079.

Huang R et al. (2016). Energy and emissions saving potential of additive manufacturing: the case of lightweight aircraft components. *Journal of Cleaner Production*. 1351559–1570.

ILO (2018). Women and men in the informal economy: A statistical picture. (accessed 6 September 2021).

ILO (2020). The future of work in the digital economy. 33.

ILO (2021). World Employment and Social Outlook, Trends 2021. (accessed 3 September 2021).

IndustriALL Global Union (2017). The challenge of Industry 4.0 and the demand for new answers. (accessed 18 October 2021).

ITC (2015). 2015: Connect, compete and change for inclusive growth. International Trade Centre. (accessed 28 September 2021).

ITC (2021). SME Competitiveness Outlook 2021: Empowering the Green Recovery. (accessed 28 September 2021).

ITU (2021). Connectivity in the Least Developed Countries: Status report 2021.

Juhn C, Murphy KM and Pierce B (1993). Wage inequality and the rise in returns to skill. *Journal of Political Economy*. 101(3):410–442.

Keep E, Mayhew K and Payne J (2006). From Skills Revolution to Productivity Miracle—Not as easy as it Sounds? *Oxford Review of Economic Policy*. 22(4):539–559.

Krugman P (2021). The New York Times. Available at https://www.nytimes.com/2021/04/15/opinion/andrew-yang-automation.html (accessed 6 September 2021).

La Porta R and Shleifer A (2014). Informality and Development. *Journal of Economic Perspectives*. 28(3):109–126.

Leuven E, Oosterbeek H and Van Ophem H (2004). Explaining International Differences in Male Skill wage Differentials by Differences in Demand and Supply of Skill. *The Economic Journal*. 114(495):466–486.

Lin K-H and Tomaskovic-Devey D (2013). Financialization and U.S. Income Inequality, 1970–2008. *American Journal of Sociology*. 118(5):1284–1329.

McKinsey (2020). The future of maintenance for distributed fixed assets Why people are key to successfully implementing technology-led maintenance transformations. (accessed 14 October 2021).

McKinsey Global Institute (2017). Available at https://www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages (accessed 7 September 2021).

McMillan M, Rodrik D and Verduzco-Gallo Í (2014). Globalization, structural change, and productivity growth, with an update on Africa. *World Development*. 63(C):11–32.

Michaels G, Natraj A and Van Reenen J (2013). Has ICT Polarized Skill Demand? Evidence from Eleven Countries over Twenty-Five Years. *The Review of Economics and Statistics*. 96(1):60–77.

Milanovic B (2015). Global inequality of opportunity: how much of our income Is determined by where we live? *Review of Economics and Statistics*. 97(2):452–460.

Milanovic B (2016a). *Global Inequality: A New Approach for the Age of Globalization*. Harvard University Press.

Milanovic B (2016b). *Global Inequality: A New Approach for the Age of Globalization*. Belknap Press: An Imprint of Harvard University Press. Cambridge, Massachusetts.

Mueller HM, Ouimet PP and Simintzi E (2017). Wage inequality and firm growth. *American Economic Review*. 107(5):379–383.

Ng A (2017). The Times They Are A-Changin' _Technology Employment and the Malaysian Economy. *KRI Discussion Paper 2017_*.

Pajarinen M and Rouvinen P (2014). Computerization Threatens One Third of Finnish Employment. 6.

Perez C (2002). *Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages*. Edward Elgar Pub. Cheltenham.

Perez C (2010). Technological revolutions and techno-economic paradigms. *Cambridge Journal of Economics*. 34(1):185–202.

Perez C (2013). Unleashing a golden age after the financial collapse: Drawing lessons from history. *Environmental Innovation and Societal Transitions*. Economic-financial crisis and sustainability transition. 69–23.

Perez C (2015). 11. Capitalism, Technology and a Green Global Golden Age: The Role of History in Helping to Shape the Future. *The Political Quarterly*. 86191–217.

Pietrobelli C and Rabellotti R (2011). Global Value Chains Meet Innovation Systems: Are There Learning Opportunities for Developing Countries? *World Development*. Special Section (pp. 1204-1270): Foreign Technology and Indigenous Innovation in the Emerging Economies. 39(7):1261–1269.

Schwab K (2013). *Fourth Industrial Revolution*. Penguin Group. London, UK u. a.

Shin N, Kraemer KL and Dedrick J (2012). Value Capture in the Global Electronics Industry: Empirical Evidence for the "Smiling Curve" Concept. *Industry and Innovation*. 19(2):89–107.

Song J, Price DJ, Guvenen F, Bloom N and von Wachter T (2019). Firming up inequality. *The Quarterly Journal of Economics*. 134(1):1–50.

Stefano VD (2018). "Negotiating the algorithm": Automation, artificial intelligence and labour protection. ILO Employment Policy Department EMPLOYMENT Working Paper. 41.

Timmer MP, Miroudot S and de Vries GJ (2019). Functional specialisation in trade. *Journal of Economic Geography*. 19(1):1–30.

UNCTAD (2004). E-commerce and Development Report 2004. (accessed 28 September 2021).

UNCTAD (2013). Global Value Chains and Development: Investment and Value Added Trade in the Global Economy. 40.

UNCTAD (2017). Rising product digitalisation and losing trade competitiveness. UNCTAD Division on Global Development Strategies. New York.

UNCTAD (2018a). Available at https://worldinvestmentforum.unctad.org/wp-content/uploads/2018/03/Panel-2-Global-Value-Chains-the-Digital-Economy-and-the-New-Industrial-Revolution.pdf (accessed 6 September 2021).

UNCTAD (2018b). Harnessing Frontier Technologies for Sustainable Development. Technology and Innovation Report, No. 2018. United Nations. New York Geneva.

UNCTAD (2019a). Structural Transformation, Industry 4.0 and inequality: Science, Technology and Innovation Policy Challenges. TD/B/C.II/43.

UNCTAD (2019b). Digital Economy Report 2019 - Value Creation and Capture: Implications for Developing Countries. United Nations publication. No. Sales No. UNCTAD/DER/2019. Geneva. (accessed 1 December 2019).

UNCTAD (2020). World Investment Report 2020. 268.

UNCTAD (2021a). Technology and Innovation Report 2021, Catching technological waves: Innovation with equity. No. UNCTAD/TIR/2020. 196.

UNCTAD (2021b). Impact of the COVID-19 pandemic on trade and development: transitioning to a new normal. (accessed 10 August 2021).

UNCTAD (2021c). Digital Economy Report 2021: Cross-border data flows and development: For whom the data flow. No. UNCTAD/DER/2021. 238.

UNCTAD (2021d). *World Investment Report 2021: Investing in Sustainable Recovery*. United Nations Conference on Trade and Development (UNCTAD) World Investment Report (WIR). United Nations.

UNDESA (2020). *World-Social-Report-2020-Chapter-2.Pdf*.

UNIDO (2017). *Accelerating Clean Energy through Industry 4.0*.

UNIDO (2019). A revolution in the making? 71.

UNIDO (2020). Industrial Development Report 2020: Industrializing in the digital age. (accessed 31 August 2021).

UNIDO (2021a). UNIDO COVID19 Assessment Thailand. (accessed 28 September 2021).

UNIDO (2021b). UNIDO COVID19 Assessment Bangladesh. (accessed 28 September 2021).

UNIDO (2021c). Industrial Analytics Platform. Available at https://iap.unido.org/articles/what-fourth-industrial-revolution (accessed 6 September 2021).

Van Reenen J (2011). Wage inequality, technology and trade: 21st century evidence. *Labour Economics*. European Association of Labour Economists, 3rd World Conference EALE/SOLE, London UK, 17-19 June2010. 18(6):730–741.

Vivarelli M (2014). Innovation, Employment and Skills in Advanced and Developing Countries: A Survey of Economic Literature. *Journal of Economic Issues*. 48(1):123–154.

World Bank (2016). *World Development Report 2016: Digital Dividends*.

World Economic Forum (2016). World Economic Forum. Available at https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/ (accessed 6 September 2021).

World Economic Forum (2018). The Global Gender Gap Report 2018. (accessed 11 October 2021).

WTO (2018). E-commerce and developing country - SME participation in global value chain. Staff Working Paper ERSD-2018-13 13 November 2018. (accessed 28 September 2021).

WTO (2019). *Global Value Chain Development Report 2017*.