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Structural transformation, Industry 4.0 and inequality: Science, technology and innovation policy challenges

Note by the UNCTAD secretariat

Summary

Structural transformation is a central process in economic development. Without an enhancement of their productive capacity and a shift of resources to higher productivity sectors, countries will not be able to deliver on the 2030 Agenda for Sustainable Development. Earlier historical cases of structural transformation resulted in productivity growth, increased employment and higher wages, creating the conditions for more equitable income distribution. But Industry 4.0 – driven by frontier technologies such as artificial intelligence and robotics – may change the rules of the game for countries embarking on a path of industrialization. As workers are displaced from low productivity sectors, higher automation may reduce the opportunities for them to find decent jobs and may put downwards pressure on wages. This may be accentuated by higher levels of market concentration that are becoming visible in digital industries. As a result, the benefits of any productivity increase may accrue to the owners of only a few firms and income distribution may become skewed to levels incompatible with social stability.

This note considers how science, technology and innovation (STI) policy can provide directionality to technological change and the deployment of technology in markets. By facilitating economic diversification and more widespread diffusion of technology, such directionality and deployment of technology will expand the benefits of Industry 4.0 to include job creation, wage growth and the fulfilment of unmet social needs. The note also considers the role of international cooperation in building capacities in countries to design and implement STI policies that harness Industry 4.0 for inclusive and sustainable development.

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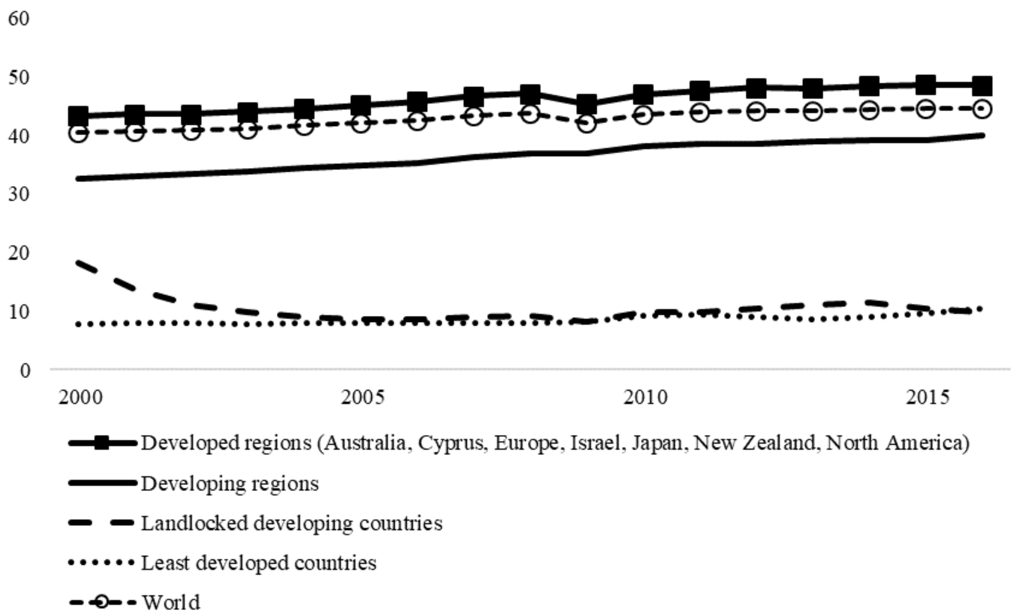
I. Introduction

1. Structural transformation is the shift of production factors such as land, labour and capital, from activities and sectors with low productivity and value added to those with higher productivity and value added, which are usually different in location and organization, as well as technologically. Higher productivity enables better living standards, making structural transformation a central process in economic development. [1] Structural transformation has involved the move of economies away from activities characterized by low wages and diminishing returns – usually associated with agriculture – towards those involving higher wages and increasing returns, such as manufacturing. Historically, structural transformations have led to increased employment and wages, creating the conditions for more equitable income distribution. Industry 4.0, driven by frontier technologies such as artificial intelligence, robotics and smart manufacturing, may change the rules of the game for countries wishing to embark on a path of industrialization. Technology at the frontier is evolving rapidly. Consequently, technological change could increase the technological gap, and hence inequality between countries. Fast technological change at the frontier may also make transitions in labour markets more difficult to manage for workers and social policymakers, and may thus increase inequality within countries.

2. Countries will only be able to deliver on the 2030 Agenda for Sustainable Development if they use their productive capacities optimally by shifting resources to higher productivity sectors. Sustainable Development Goal 9 targets this transition towards higher productivity. Yet, value added from high productivity sectors, particularly manufacturing, remains low in the least developed countries and landlocked developing countries and is even diverging from other country groupings. This difference in value added leads to a divergence in productivity trends and in the technology gap (see figure).

Sustainable Development Goal indicator 9.b.1: Proportion of medium and high-technology industry value added in total value added, selected regions, 2000–2015
(Percentage)



Source: United Nations Global Sustainable Development Goal Indicators Database.

3. Further, automation, fuelled by rapid developments in artificial intelligence and robotics, may destroy jobs in a first round of effects. While new jobs are likely to be created, their number may be lower, and this might take time. This could displace workers and put

[1] UNCTAD, 2018a, *The Least Developed Countries Report 2018: Entrepreneurship for Structural Transformation: Beyond Business as Usual* (United Nations publication, Sales No. E.18.II.D.6, New York and Geneva).

downward pressure on wages. But the impact of Industry 4.0 on income distribution and inequality will not be the result of technological change alone. The effects on inequality will also depend on a combination of economic, political and regulatory factors. For example, access to education, choices in taxation and in public expenditure, and labour market institutions can influence outcomes for different groups in society.

4. This note will consider how STI policy can guide and support technological change and the deployment of technology to facilitate economic diversification and more widespread technology diffusion, and thus reduce inequalities. STI policy could help make it possible to extend the benefits of Industry 4.0 to include job creation, wage growth and the fulfilment of unmet social needs. Further, the note will consider the role of international cooperation in starting a dialogue on recent technological change and in building countries' capacities to design and implement STI policies that harness Industry 4.0 for inclusive and sustainable development.

II. The role of technology and innovation in structural transformation and Industry 4.0

A. The role of technology and innovation in structural transformation

5. Structural transformation in many developing regions followed similar patterns and resulted in productivity growth, increased employment and higher wages, creating the conditions for increased prosperity and associated improvements in the access to many public goods, including health and education, that are key to social equity. Industrialization has been an essential element in the process of structural transformation, given the potential for productivity gains in manufacturing and the associated increases in wages that often spill over to other sectors of the economy when the labour surplus in agriculture is reduced. This classical pattern of structural transformation was most pronounced in East Asia, where structural transformation and rapid industrial growth occurred at the same time.[2] There has been a debate about the continued relevance of manufacturing to structural transformation, where alternative views argue that services can drive this process.

6. Historically, the main emphasis of structural transformation has been a shift from agriculture towards manufacturing. But broad economic sectors – agriculture, mining, industry and services for example – can hide large differences in terms of productivity between specific activities. Therefore, more recently, structural transformation is considered to involve not only shifts between sectors, but also within sectors, towards activities that are more knowledge intensive and generate higher value added. In this wider definition of structural transformation, new technologies and innovation are key factors that drive the development of new products, processes, organizational methods and markets.[3] These more complex products can be found in any sector (for example agriculture and services), not only in manufacturing. In that regard, structural change is essential for developing and developed countries alike, to catch up in the case of the former and to stay at the technological frontier in the latter.

7. The upgrading of production and its diversification are ultimately the result of technological innovation, which often takes the form of emulation of world leaders in technology. At the outset, this emulation-led technological learning involves direct copying, reverse engineering, followed by marginal modifications of products and processes. This was witnessed during the early stages of the development process in countries such as the United Kingdom of Great Britain and Northern Ireland, the United States of America, Japan and more recently China and other emerging economies. The successful undertaking of such emulation-led technological learning could be made available by the absorptive capabilities

[2] UNCTAD, 2016, *Trade and Development Report, 2016: Structural Transformation for Inclusive and Sustained Growth* (United Nations publication, Sales No. E.16.II.D.5, New York and Geneva).

[3] UNCTAD, 2014, *The Least Developed Countries Report 2014: Growth with Structural Transformation: A Post-2015 Development Agenda* (United Nations publication, Sales No. E.14.II.D.7, Geneva).

of respective countries. Absorptive capabilities are path dependent. The past accumulation of technological knowledge influences the potential of absorbing new knowledge in the future.[4]

8. The literature on structural change emphasizes the idea that some sectors are more conducive to future economic development than others.[5] At the same time, diversification is path dependent. A country's present production capabilities are likely to influence what the country is going to produce in the future. Recent research has generated product space maps that illustrate this path dependency.[6] These maps show that some products are better connected to other products. Therefore, the technology used and innovation in these products can facilitate further innovation in the future. Other products are like a dead end – the productive and technological capabilities needed for these products are unlikely to be useful for the development of new products, so they do not generate further innovation and diversification. Once a country reaches the capabilities of their production, it becomes difficult to use these capabilities to move to another type of production. Therefore, policies targeting structural transformation need to set the direction of innovation.

B. Industry 4.0: Status and trends

9. Industry 4.0 refers to the increased use of automation and data exchange in manufacturing – a current trend – resulting in smart and connected production systems.[7] It is one of the major drivers of the fourth industrial revolution. Industry 4.0 is associated with increased digitization in manufacturing through connectivity, the industrial Internet of things, big data collection and analytics, new forms of interaction between humans and machines, improvements in using digital instructions due to robotics and three-dimensional (3D) printing.

10. The current status of several frontier technologies associated with Industry 4.0 are presented in table 1. Artificial intelligence is the most prolific in terms of the number of publications and patent collections. The Internet of things is largest in terms of market size, partly because of the wide range of components encompassed by the technology (i.e. software, services, connectivity and devices) as well as large-scale industrial applications (the industrial Internet of things). It is followed by big data technologies, robotics, artificial intelligence, 3D printing and the fifth generation of mobile services (5G).

11. A few large companies from Asia, Europe and the United States dominate the market of frontier technologies such as artificial intelligence, the Internet of things and big data through their provision of all-in-one platforms that include hardware, storage, servers, data centre spaces, network components, software and cloud platforms. As more users prefer pay-as-you-go services by those providers to save costs instead of building their own system, the concentration of market share and profits increases as competitors with limited service offerings find it difficult to compete.

[4] M Cimoli, G Dosi and JE Stiglitz, 2009, The political economy of capabilities accumulation: The past and future of policies for industrial development, in M Cimoli, G Dosi and JE Stiglitz, eds., 2009, *Industrial Policy and Development: The Political Economy of Capabilities Accumulation*, Oxford University Press, Oxford.

[5] For example, see R Prebisch, 1959, Commercial policy in the underdeveloped countries, *The American Economic Review*, 49:251–273.

[6] CA Hidalgo, B Klinger, AL Barabási and R Hausmann, 2007, The product space conditions the development of nations, *Science*, 317(5837): 482–487.

[7] United Nations Industrial Development Organization, 2017, *Accelerating Clean Energy through Industry 4.0: Manufacturing the Next Revolution*, Vienna.

Table 1
Status of frontier technologies

Criteria	*Artificial intelligence*	*Internet of things*	*Big data*	*5G*	*3D printing*	*Robotics*
Publications	*330 471*	*51 625*	*58 500*	*5 132*	*13 980*	*212 382*
Patent collection	38 486	24 654	7 986	3 174	10 270	8 024
Price	Insurance fraud-detection tool: $100,000–$300,000, Chatbots: $30,000–$250,000	Electrocardiography monitors: $3,000–$4,000 Building and home automation: from $50,000	Building and maintaining a 40-terabyte data warehouse: $880,000 per year	$10–$20 more per month than 4G	$200–$100,000	Industrial robots: $25,000–$400,000 Humanoid robots: $500–$2,500,000
Market size	$16.06 billion (2017)	$130 billion (2018)	$31.93 billion (2017)	$608.3 million (2018)	$9.9 billion (2018)	$31.78 billion (2018)
Major producers	Alphabet, Amazon, Apple, International Business Machines (IBM), Microsoft	Alphabet, Amazon, Cisco, IBM, Microsoft, Oracle, PTC, Salesforce, SAP [Systems, Applications and Products in Data Processing] (Internet of things cloud platform)	Alphabet, Amazon, Dell Technologies, Hewlett Packard Enterprise, IBM, Microsoft, Oracle, SAP, Splunk, Teradata (storage platforms, analytics)	Network equipment suppliers: Ericsson, Huawei, Nokia, ZTE Chip makers: Huawei, Intel, MediaTek, Qualcomm, Samsung Electronics	3D Systems, ExOne, Hewlett Packard Enterprise, Materialise, Stratasys	Industrial robots: ABB, FANUC, KUKA, Mitsubishi Electric, Yaskawa Electric Humanoid robots: Hanson Robotics, Pal Robotics, Robotis, SoftBank Robotics
Main users	Retail, banking, discrete manufacturing	Consumer, insurance, health-care providers	Banking, discrete manufacturing, professional services	Energy utilities, manufacturing, public safety	Discrete manufacturing, health care, education	Discrete manufacturing, process manufacturing, resource industries

Source: UNCTAD, forthcoming, *Technology and Innovation Report 2020*. Publication and patent collections data cover the period of 1996–2018 and were retrieved from the Elsevier Scopus database and Patentscope database of the World Intellectual Property Organization, respectively.

Notes: Market size is defined as the total revenue in a segment. Major producers are the companies most commonly referred to as major players through online search. Top users were identified based on spending in technologies in a specific year worldwide, except 5G, for which estimations were used instead.

III. The potential impact of Industry 4.0 on structural transformation and inequality

12. Industry 4.0 is likely to have both direct and indirect impacts on inequality. First, the network nature of digital applications that comprise Industry 4.0 increasingly results in a world in which winners take all, causing high levels of market concentration. As market power concentrates on a few players, there are opportunities for those firms to raise their profit margins. This, combined with monopsony power in the labour market, can contribute to higher shares of capital in income distribution at the expense of labour. Routine jobs may vanish as they are automated, and even skilled labour may lose out to artificial intelligence and big data. Industry 4.0 can also affect jobs indirectly in less industrialized and more labour-intensive countries through changes in trade and specialization patterns, which could have an impact on countries' industrialization strategies and their efforts to achieve structural transformation.

A. Impact on market concentration and profits

13. Industry 4.0 can affect market concentration and profits due to network and scale effects. A few technology companies with access to large amounts of data and funding, for example, may succeed in dominating certain technologies and markets by feeding their data into powerful artificial intelligence applications and acquiring start-ups before they can become potential competitors.[8] Market concentration is present in the markets for many technologies listed in table 1 and the high market share and profitability of the few firms that dominate them. This market power is often a direct consequence of innovation, given that Schumpeterian rents (the higher profits that innovators earn by being the only providers of a new product or service) are an essential incentive for product innovation. In particular, process innovation in Industry 4.0 is expected to replace workers, reducing costs and potentially prices, which in turn could further increase market shares and profits, leading to inequality among firms.

14. However, the distribution of income in a society depends on a combination of historical, economic and political factors. The social and economic frameworks in which societies operate and the way different players and groups in society negotiate distributional issues through the political process can increase or reduce inequalities. Tax policies, for example, could address tax optimization by some dominant large multinational companies. Pensions or social services can be financed with charges on salaries or with taxes on the carbon-intensity of products, with different outcomes on employment and on income distribution. Competition policies should be active, vigilant and updated regularly to address firms' challenges relating to barriers to market entry, price collusions, high asymmetry of information and other new forms of anticompetitive practices.[9]

B. Impact on jobs

15. Industry 4.0 may have an impact on employment in developed and developing countries. Most studies in this regard have focused on the more advanced economies. For example, some estimates suggest that large shares of United States jobs are at risk of automation in the coming decades as digital technologies increasingly replace humans at work.[10] Others see a more modest impact across occupations (table 2).[11] The variation in the

[8] United Nations Industrial Development Organization, 2018, *Industry 4.0: The Opportunities behind the Challenge*, Vienna.

[9] UNCTAD, 2018b, *Trade and Development Report 2018: Power, Platforms and the Free Trade Delusion* (United Nations publication, Sales No. E.18.II.D.7, New York and Geneva).

[10] CB Frey and M Osborne, 2017, The future of employment: How susceptible are jobs to computerization? *Technology Forecasting and Social Change*, 114:254–280.

[11] For example, see M Arntz, T Gregory, and U Zierahn, 2016, The risk of automation for jobs in OECD Countries: A comparative analysis, OECD Social, Employment and Migration Working Papers, No. 189, OECD Publishing, Paris.

estimates are attributed to the various assumptions such as the complete or partial automation of occupations.[12] Some studies suggest that the negative effects of robotization will be higher in the lower-income regions of major economies.[13]

Table 2
Estimated impact of Industry 4.0 technologies on jobs

Estimate	*Time frame*	*Technology*	*Study*
47 per cent of total United States employment at high risk of being automated	10–20 years	Artificial intelligence and robotics	Frey and Osborne, 2017
9 per cent of total employment in the United States and 21 countries of the Organization for Economic Cooperation (OECD) and Development at high risk of being automated	10–20 years	Artificial intelligence and robotics	Arntz et al., 2016, 2017
50 per cent of today’s work activities worldwide could be automated	By 2055	Artificial intelligence and robotics	McKinsey Global Institute, 2017[14]
8.5 per cent of the global manufacturing workforce, mostly in lower-income regions of major economies, could become redundant	20 years	Industrial robots	Oxford Economics, 2019

Source: UNCTAD compilation.

16. Among the few studies focusing on developing countries, the *Technology and Innovation Report 2018: Harnessing Frontier Technologies for Development*[15] argues that automation may have an impact on employment in developing countries by eroding their comparative advantage in abundant low-cost and low-skilled workers and reducing the potential of manufacturing sector to absorb large domestic labour surpluses.

17. At the moment, there are limited data on the subject. Today the use of industrial robots globally remains small and amounts to less than two million units. Robots are concentrated in the automotive, electrical and electronics industries, and in a few countries, such as China, Germany, Japan, the Republic of Korea and the United States. Routine tasks in manufacturing and service jobs are being replaced but low-wage manufacturing jobs in areas such as clothing factories remain largely unaffected by robotization.[16]

18. There is concern that technological progress could not only disrupt labour markets in the short term, but could also reduce the demand for labour in the long term (that is to say, labour is racing against the machine).[17] This runs counter to the previously well-accepted

[12] For example, see M Arntz, T Gregory, and U Zierahn, 2017, Revisiting the risk of automation, *Economics Letters*, 159:57–160.

[13] Oxford Economics, 2019, How Robots Change the World: What Automation Really Means for Jobs and Productivity.

[14] McKinsey Global Institute, 2017, A Future that Works: Automation, Employment and Productivity, McKinsey Global Institute.

[15] UNCTAD, 2018c, *Technology and Innovation Report 2018, Harnessing Frontier Technologies for Development* (United Nations publication, Sales No. E.18.II.D.3, New York and Geneva).

[16] UNCTAD, 2017, *Trade and Development Report 2017: Beyond Austerity – Towards a Global New Deal* (United Nations publication, Sales No. E.17.II.D.5, New York and Geneva).

[17] E Brynjolfsson and A McAfee, 2011, *Race against the Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy*, Digital Frontier Press, Lexington, Massachusetts.

hypothesis of skill-biased technological change, in which technology complements skilled workers.[18] Many point to the recent phenomenon of job polarization, in which technological change has had a greater effect on middle-skilled workers from a range of developed countries than low- and high-skilled workers, as evidence of the loss of relevance of this hypothesis.[19]

19. A competing hypothesis considers routine-replacing technological change,[20] which predicts an increased demand for labour in non-routine relative to routine tasks. Some frontier technologies are expected to benefit workers performing non-routine tasks, both in manual and cognitive jobs, which can affect both high- and low-paid jobs. Workers performing routine tasks are expected to face further pressures from ever more capable machines and artificial intelligence software. More powerful artificial intelligence could increase job polarization and wage inequality, particularly in many developed countries.

20. In empirical research, the effect of automation and robots on jobs and wages is mixed. For example, a study using panel data on robot adoption in industries in 17 countries from 1993 to 2007 found that increased robot use did not significantly reduce total employment. However, it reduced the employment share of low-skilled workers.[21] Another study, focusing on local labour markets in the United States between 1990 and 2007, found that the increase in industrial robot use resulted in large and robust negative effects on employment and wages.[22] On the other hand, another study using the same empirical design but applied to regions in Germany, found evidence of the positive effects of automation on wages and no changes in total employment, although there was a change in the composition of employment.[23]

21. Routine-replacing technological change could affect inequalities in other areas such as gender and age. For example, recent research using Dutch microdata and firms' automation expenditures between 2000 and 2006 shows that automation increases the probability of workers leaving their employers. Further, days worked are reduced. These two factors result in a five-year cumulative wage loss of about 8 per cent of one year's earnings. This loss is disproportionally borne by older workers and workers with longer firm tenure.[24] In terms of the differential impact of Industry 4.0 on gender, some studies have found that women, on average, perform more routine or codifiable tasks than men across all sectors and occupations – tasks that are more prone to automation.[25] Other studies suggest that the aggregated potential job displacements and job gains for women and men are of similar magnitude, but the composition of jobs affected differ, given the ways that women and men are differently represented across occupations.[26]

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[18] For example, see the survey in D Acemoglu and D Autor, 2011, Skills, tasks and technologies: Implications for employment and earnings, *Handbook of Labour Economics*, 4B:1043–1171.

[19] For example, see M Goos, A Manning and A Salomons, 2014, Explaining job polarization: Routine-biased technological change and offshoring, *American Economic Review*, 104(8):2509–2526.

[20] For example, see D Autor, 2013, The "task approach" to labour markets: An overview, *Journal for Labour Market Research*, 46(3):185–199.

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

[22] D Acemoglu and P Restrepo, 2017, Robots and jobs: Evidence from US [United States] labour markets, National Bureau of Economic Research Working Paper 23285, Cambridge, Massachusetts.

[23] W Dauth, S Findeisen, J Suedekum, and N Woessner, 2017, German robots: The impact of industrial robots on workers, Centre for Economic Policy Research Discussion Paper 12306, London.

[24] J Bessen, M Goos, A Salomons and W van der Berge, 2019, Automatic reaction: What happens to workers at firms that automate? Boston University School of Law, Law and Economics Research Paper No. 19-2.

[25] M Brussevich, E Dabla-Norris, C Kamunge, P Karnane, S Khalid and K Kochhar, 2018, Gender, technology and the future of work, International Monetary Fund Staff Discussion Note, SDN/18/07.

[26] McKinsey and Company, 2019, *The Future of Women at Work: Transitions in the Age of Automation*, McKinsey Global Institute.

C. Industry 4.0 and the technological gap

22. A critical determinant for developing countries' ability to catch up will be the diffusion of frontier technologies associated with Industry 4.0 in their productive sectors. However, there is considerable uncertainty regarding this issue. Some frontier technologies such as cloud computing and 3D printing create new opportunities for innovation, even in the poorest countries. With better infrastructure and a skilled labour force, however, more industrialized economies are enjoying a comparative advantage in industries, services and segments of value chains that use frontier technologies – and could widen the technological gap between developed and developing countries.

23. Even when frontier technologies are adopted in more traditional sectors, this may not be an advantage for less industrialized countries. Developing countries diversify their economies by emulating industries that already exist in more industrialized countries, which requires the capacity to absorb and adapt technologies to the receiving country's context. This emulation tends to be an incremental process, and the industries that are more likely to be emulated are those that use a set of capabilities that largely overlap with those already used by the existing industries in the economy. When countries at the technological frontier apply the latest technologies to improve the production in traditional sectors, they increase the technological gap, which makes the process of emulation for the less industrialized countries more challenging.

24. The technological gap between frontier and other firms in developed countries is widening too. Recent research in OECD countries suggests that global frontier technologies are diffused to average firms only when the most productive national frontier firms test and adapt these technologies to local circumstances.[27] This slows technological diffusion and enables frontier firms to capture bigger market shares and profits and thus contributes to inequality through direct and indirect effects: profits and fewer good jobs, respectively. Policies such as favourable product market regulations, pro-competition reforms and incentives for higher collaboration in research and development may facilitate the catching up of average firms with frontiers.

25. Moreover, high value added activities tend to concentrate geographically in clusters, adding a spatial dimension to inequality. Concentration may be even stronger in the case of advanced Industry 4.0 technologies, as is already the case in the United States (for example, Silicon Valley attracts many different technologies, but large cities such as Portland specialize in semiconductors, and Seattle and Boston, in life sciences).[28] Global venture capital financing innovation and start-ups are also highly concentrated, with only 10 large cities across the world attracting over 60 per cent of venture capital investment each year.[29] This is contrary to the premise that geographical location would become irrelevant as a result of information and communications technologies. Innovation policy needs to consider not only the impact of interventions on clusters and industrial parks, but also on regional inequality within countries. In this regard, investment in skills, technology and infrastructure that support the geographical distribution of resources and benefits may be particularly important.

IV. Science, technology and innovation policies in the age of Industry 4.0

26. Some forms of contemporary innovation have ignored the social and environmental dimensions of sustainable development and have contributed to exacerbating inequalities. An important question for STI policymakers today is not only how to encourage more

[27] D Andrews, C Criscuolo and P Gal, 2016, The best versus the rest: The global productivity slowdown, divergence across firms and the role of public policy, OECD Productivity Working Paper No. 5.

[28] E Moretti, 2012, *The New Geography of Jobs*, Houghton Mifflin Harcourt Publishing, New York.

[29] R Florida and I Hathaway, 2018, How the geography of start-ups and innovation is changing, *Harvard Business Review*, 27 November, available at https://hbr.org/2018/11/how-the-geography-of-startups-and-innovation-is-changing (accessed 28 August 2019).

innovation, but how to stimulate the right forms of innovation for more inclusive and equal societies, while discouraging harmful innovation. This section examines policies that support Industry 4.0 and the challenges in designing and implementing STI policies that take into consideration the possible effects on inequality. Successful innovation policy is fundamental for growth-enhancing structural transformation and maintaining a country's competitiveness. Nevertheless, an intrinsic challenge in innovation policymaking is that its first-round effects tend to increase inequality within countries. STI policy must address this risk as an integral part of the innovation policy portfolio.

A. Promoting the use, adoption, adaptation and development of technologies associated with Industry 4.0

27. To benefit from Industry 4.0, countries must learn, adopt, adapt and disseminate knowledge and technologies, which is a challenge. To do so, countries take further steps to strengthen the effectiveness of their innovation systems, which tend to be weaker and more prone to systemic failures and structural deficiencies in developing countries. UNCTAD has written extensively on innovation systems and how to build an enabling environment for STI.[30]

28. In the context of Industry 4.0, infrastructure, especially digitalization and connectivity, is a key element of an enabling environment. Developing countries need to build their infrastructure with a specific emphasis on providing reliable access to electricity and connectivity, ensuring affordable access to information and communications technologies and overcoming gender, generational and digital divides. It is equally important that digital policies be calibrated according to countries' readiness to engage and benefit from the digital economy.

29. Capabilities to adopt and adapt the technologies of Industry 4.0 into countries' existing production base is another key area for policymakers to consider. This requires education and developing digital skills and competencies. Digital competencies include technical skills, but also generic and complementary skills. Different types of digital skills are needed to adapt to new technologies. There are those skills that are necessary for the adoption and the basic use of technologies, those for the creative use and adaptation of technologies, and those for the creation of new ones.[31]

30. Developing countries must have appropriate skills to introduce modifications to new technologies associated with Industry 4.0. Education and training programmes that focus on digital skills for all should be inclusive and accessible to everyone. Other types of competencies vary across sectors, countries and industrial development. In countries where technology development remains in its early stages, basic technical skills and generic skills are the most required. Countries in which the manufacturing sector dominates economic growth will require a workforce with specialized skills in robotics, automation and the Internet of things.[32] Given that these capacities are usually learned by doing, there is a need to foster an ecosystem of firms in these technology sectors to provide the jobs, training and experience required to master these technologies.

31. The transfer and diffusion of technology in Industry 4.0 from new technology sectors to traditional production sectors speed up industrial structural transformation and upgrading. Countries should foster these linkages by supporting collaborative research and strengthening business partnerships. Effective research and business partnerships can help traditional production sectors benefit from different channels of technology diffusion, including foreign direct investment, trade, intellectual property rights, patents and the exchange of knowledge

[30] See for example, UNCTAD, 2018c; UNCTAD, 2019, *A Framework for Science, Technology and Innovation Policy Reviews: Harnessing Innovation for Sustainable Development* (United Nations publication, Geneva); UNCTAD, forthcoming, *The Impact of Rapid Technological Change on Sustainable Development*.

[31] P DiMaggio, E Hargittai, C Celeste and S Shafer, 2004, Digital inequality: From unequal access to differentiated use, in K Neckerman, ed., *Social Inequality*, Russell Sage Foundation, New York.

[32] E/CN.16/2018/3.

and know-how. This interrelation and the exchange of information relating to consumer needs, technological possibilities and opportunities for increasing competitiveness are the fuel of innovation in these new technologies. While collaborative innovation can occur spontaneously, it often requires active facilitation by government or non-government actors, especially when dealing with social and environmental challenges.[33]

32. Finally, countries could also build capacity to assess the social, economic and environmental impacts of Industry 4.0 and to translate this assessment into effective policies, strategies and programmes. Technology foresight and assessment involves bringing together key stakeholders and sources of knowledge to develop strategic visions and intelligence to shape the future. Developing capacity in technology foresight can enable countries to identify and exploit the potential of Industry 4.0 technologies, pinpoint priority technologies in the short, medium and longer term, and assess potential effects, including on inequality.

B. Innovation directed towards reducing inequalities

33. Industry 4.0 could widen inequalities because not everyone benefits immediately from the new products, services and opportunities created. STI policy can draw from a broad range of instruments, from regulatory measures and economic and fiscal instruments, to education and regional innovation policies that aim to support innovation. Without giving up on the fundamental goal of encouraging innovation, policymakers can influence the direction of change and mitigate the risks of increased inequality triggered by Industry 4.0.

34. This directionality refers to the extent to which the chosen STI policy mix is oriented towards sustainable and inclusive development. In this context, giving directionality to STI policy instruments (such as research and development and innovation funding; tax incentives for research and development and technology adopters; public procurement; the creation of clusters, industrial zones and technology parks; and the provision of training and business advisory services) means setting collective priorities first, such as reducing inequality between firms, social groups, individuals or regions.

35. For example, given that technology must be affordable to low-income customers and accessible to the larger population, STI policy can provide directionality towards reducing the cost of technology creation and deployment. Public investment can provide incentives. In addition, STI policy could support STI commercialization by shifting emphasis towards innovation and directing incentives towards the widespread adoption of frontier technologies by the market.

36. Gender-inclusive innovation policies may be aimed at increasing women's participation as researchers, innovators or entrepreneurs; at including women as decision makers in technological systems; or at developing new technologies, products and services that improve women's lives – in the areas of energy, water and sanitation, health, or financial education. Technical and vocational training can also empower women to play a role in technology sectors associated with Industry 4.0.

37. Youth-oriented education and training policies can also be helpful in equipping the future labour force with appropriate skills. Policymakers may consider developing programmes to increase interest in technologies related to Industry 4.0 and focusing on entrepreneurship, marketing and creativity.

38. STI policies aimed at reducing inequalities should also consider strategies and mechanisms that create an enabling environment for new innovation approaches, such as pro-poor, inclusive, frugal, grassroots, and social innovation.[34] To be effective, STI policies need to build synergies with other economic policies (industrial, fiscal and educational policies) and involve a wide range of actors. Policies should encourage academia and civil society organizations to engage with the private sector to develop and scale up solutions. Creating a mechanism to promote the mobility of personnel from academia to the private sector is

[33] UNCTAD, 2018c.

[34] See UNCTAD, 2017, *New Innovation Approaches to Support the Implementation of the Sustainable Development Goals* (United Nations publication, New York and Geneva).

necessary to equip the latter with technological capabilities to innovate, to generate more market-oriented and social innovations and to enable their diffusion to marginalized and vulnerable communities.

39. STI policy can support the establishment of science parks, incubators, accelerators, and innovation labs to develop innovative ideas and foster innovation clusters. These clusters facilitate experimentation and benefit from the geographical concentration of knowledge and skills, which allows for faster technological development. At the same time, STI policy may promote the scaling up and dissemination of successful innovations that emerge from these innovation hubs to reduce regional inequalities.

40. Recent work by UNCTAD shows that large and growing differences between industrialized urban areas and agricultural rural regions, with gaps in income and education, have led some national Governments to take measures to reduce regional inequalities through decentralized investment in STI. Regional and local Governments may also use the power of interaction through innovation systems to support place-based economic opportunities and local systems of innovation and production.[35]

C. Policy measures to ensure that no one is left behind

41. Social protection systems can provide workers with security during potential labour market disruptions caused by the emergence of Industry 4.0. However, only a third of the world's population is covered by comprehensive social security, while over half of the workforce lacks social security completely.[36] In addition, social protection systems worldwide are under pressure because of the ageing of the population, reduction of the tax base and low-interest rates.[37] Several redistribution policies have been proposed recently to address these challenges, including the taxation of capital, robots and other technologies to provide additional revenue for social security systems. OECD is looking at possible solutions to the taxation challenges arising from the digitalization of the economy.[38] Other proposals include the introduction of universal basic income schemes. Evidence about the impact of some of these policies, especially universal basic income schemes, remains scarce, and policy experimentation may be needed.

42. Other policies can support people who lose their jobs and experience workforce transitions.[39] Life-long learning initiatives, involving the training and re-training of workers, are increasingly the joint responsibility of Governments, employers and workers. Apprenticeship programmes combining work- and school-based learning may especially support young generations in transitioning from school to work. Governments may also support workers in job transitions by combining skills development with improved job matching, personal counselling and placement services.

43. Policies can also support employers' and workers' organizations or trade unions to tackle new challenges in the relationship between workers and employers in the context of Industry 4.0. As noted by the Global Commission on the Future of Work of the International Labour Organization, informal micro- and small enterprises often struggle to adequately represent their interests through employers' organizations, while demographic shifts and changes in the organization of work make it difficult for workers to organize themselves.[40] With policy support, regulatory and legal reforms, collective bargaining could protect

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[35] UNCTAD, forthcoming, *The Impact of Rapid Technological Change on Sustainable Development*.

[36] International Labour Organization, 2017, *World Social Protection Report 2017–19: Universal Social Protection to Achieve the Sustainable Development Goals*, International Labour Office, Geneva.

[37] T Balliester and A Elsheikhi, 2018, The future of work: A literature review, Research Department Working Paper No. 29, International Labour Office, Geneva.

[38] OECD, 2019, *Programme of Work to Develop a Consensus Solution to the Tax Challenges Arising from the Digitalization of the Economy*, OECD/Group of 20 Inclusive Framework on BEPS [Base Erosion and Profit Shifting Project], OECD, Paris.

[39] McKinsey Global Institute, 2017, *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation*, chapter 5, McKinsey and Company.

[40] International Labour Organization, 2019, *Work for a Brighter Future*, Global Commission on the Future of Work, International Labour Office, Geneva.

vulnerable workers from precarious employment, substandard conditions and marginalization.

44. To remain relevant, workers' trade unions need to anticipate and adjust their organizing and collective bargaining methods to the changing circumstances of the economy and labour markets. 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.

45. On the other hand, employers' organizations can contribute to 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.

46. More and more countries are developing strategies and policies to harness Industry 4.0 (i.e. on artificial intelligence, the Internet of things, 5G and digitization), some of which also consider combating potential increases in inequalities. Provisions regarding the development of appropriate skills are a common feature of these policy documents. In Austria, the national policy for information technology didactics and eLearning, for example, is integrated within the national school system. When pilot projects and initiatives prove to be successful, they are transferred to the entire school system.[41] In Japan, the Council for Social Principles of Human-centric Artificial Intelligence warns that opportunities for education in artificial intelligence literacy need to be widely provided in early childhood, primary and secondary education, as well as for the current workforce and elderly people.[42] In Finland, a working group was established to make recommendations on how the country can become one of the frontrunners in the application of artificial intelligence. To provide life-long learning, the group suggested setting up a "skills account" for each inhabitant, to accumulate funds entitling the holder to training. The costs are to be covered by the central Government, employers and employees.[43]

V. The role of international cooperation in structural transformation

47. Shaping a country's comparative advantage and structural transformation does not occur in isolation from today's interconnected economies and even polities. International cooperation contributes to exchanging knowledge, best practices, lessons learned and building national capacities to design and implement equitable STI policies in view of Industry 4.0. Timely international cooperation can thus shape STI policies that influence future economic and social trajectories, before countries are prevented from accessing certain technological benefits due to path dependency of technological capabilities.[44]

48. Further, technological change tends to occur faster than policy adapts to it. Serious concerns regarding questions with a global reach about governance, equality, and equity arise as the gap between policymaking and technological change widens. Consequently, international mechanisms and forums are necessary to better understand the evolution of new technologies and their societal, economic and environmental impacts. These issues have been considered in recent work by UNCTAD and the Commission on Science and Technology for Development.[45]

[41] Contribution from the Government of Austria to the twenty-second session of the Commission on Science and Technology for Development, 13–17 May 2019, available at https://unctad.org/meetings/en/Contribution/ecn162019c01_Austria_en.pdf (accessed 9 July 2019).

[42] Contribution from the Government of Japan to the twenty-second session of the Commission on Science and Technology for Development, 13–17 May 2019, available at https://unctad.org/meetings/en/Contribution/ecn162019c07_Japan_en.pdf (accessed 9 July 2019).

[43] Ministry of Economic Affairs and Employment of Finland, 2018, *Work in the Age of Artificial Intelligence: Four Perspectives on the Economy, Employment, Skills and Ethics*, Publications of the Ministry of Economic Affairs and Employment 21/2018, Helsinki.

[44] TD/B/C.II/36.

[45] See, for example, E/CN.16/2019/2 or UNCTAD, 2018c.

49. Technology assessments, for example, need to consider the global or regional consequences of the deployment of new technologies. They should also involve multiple stakeholders and support national policymakers in improving their capacities to harness Industry 4.0 optimally.[46]

50. In its resolution 73/247 on industrial development cooperation of 20 December 2018, the General Assembly of the United Nations addresses industrial development cooperation and recognizes the potential benefits derived from structural transformation through Industry 4.0, among other concepts of economic transformation.[47] Several initiatives illustrate the role of international cooperation in making Industry 4.0 inclusive and sustainable.

51. For example, to support structural transformation linked to Industry 4.0, the Group of 20 has launched several activities. The Blueprint on Innovative Growth initiative aims to support the 2030 Agenda through cooperation on innovation, Industry 4.0 and the digital economy and is supplemented by the Group of 20 New Industrial Revolution Action Plan.[48] Further, the Group of 20 Initiative on Supporting Industrialization in Africa and Least Developed Countries proposes to advance industrialization and inclusive growth in Africa and the least developed countries through voluntary policy options.[49]

52. OECD work relating to Industry 4.0 aims to inform policymakers about possible future developments in frontier technologies and to provide advice on how to foster a policy environment that allows countries to reap the benefits of technology.[50] This work also informed the OECD report for the Group of 20 on the Next Production Revolution, which posits that the coming transformations are going to be challenging for all countries, especially for developing countries. The effects might be mitigated by rapid cost reductions of some technologies, as well as better means of knowledge diffusion.[51] The latter will be supported by successful international cooperation.

53. The United Nations Industrial Development Organization plays an active role in bringing about economic transformation in developing countries through its Networks for Prosperity initiative, as well as its work on South–South and triangular industrial cooperation, international technology centres, and investment and technology promotion offices.[52]

54. UNCTAD contributes to international cooperation in STI policymaking by providing a forum for discussion, country reviews, South–South and inter-agency cooperation and thought leadership.

55. UNCTAD STI policy reviews aim to support national Governments in aligning their STI policies with their national development strategies and in reaching the Sustainable Development Goals. The findings of these reviews tend to underline the need for functional innovation systems to build comparative advantages that create higher value added activities and exports. STI policy reviews in developing countries also commonly identify an asymmetry between policymaking reality, which often follows the linear science-push model of innovation and the multidimensional approach to policymaking outlined in the 2030 Agenda. Such an approach is particularly relevant if the inclusiveness implications of rapid technological change are to be addressed meaningfully. Therefore, capacity-building activities need to strengthen STI policymakers' capabilities to design, implement, monitor

46 E/2019/78.

47 A/RES/73/247.

48 A/71/380.

49 A/RES/73/247.

50 OECD, 2017a, *The Next Production Revolution: Implications for Governments and Businesses*, OECD Publishing, Paris.

51 OECD, 2017b, The Next Production Revolution: A Report for the G [Group of] 20. See https://www.oecd.org/g20/topics/digitalisation-and-innovation/ (accessed 23 July 2019).

52 United Nations Industrial Development Organization, 2019, Partnerships for prosperity, available at https://www.unido.org/our-focus-cross-cutting-services/partnerships-prosperity (accessed 23 July 2019).

and assess effective policies to leverage STI in Industry 4.0 for the Sustainable Development Goals.[53]

56. Using the expertise from the STI policy reviews, UNCTAD is contributing to the STI for Sustainable Development Goal road maps workstream of the Inter-Agency Task Team on STI for the Sustainable Development Goals (IATT) in regard to the Technology Facilitation Mechanism. The road maps are expected to become a multi-stakeholder engagement tool to develop a framework for coherent national STI policymaking, which can benefit from the experiences of developed and emerging countries to encourage learning and perhaps help in leapfrogging into Industry 4.0. A road map should help to plan, communicate and enable actions, track progress and foster a learning environment to accelerate the achievement of the Sustainable Development Goals.[54]

57. Successful structural transformation requires the right capabilities to implement insights from policy reviews and road maps. Consequently, national and regional capacity-building is important for the adoption of Industry 4.0. IATT is actively developing and implementing a programme of joint capacity-building activities at the regional level to address this need.

58. Reflecting its perspective on South–South collaboration, UNCTAD, in its capacity as the secretariat of the Commission on Science and Technology for Development, is working with the Government of China to facilitate training for STI policymakers of developing countries. The courses cover the experience of China in STI policymaking and the development and management of high-technology parks and incubators. In 2018, more than 30 experts and policymakers from States members of the Commission participated to learn about the experience of China in shaping STI policymaking and building an STI enabling environment. The next round of training sessions is planned for autumn 2019.

VI. Conclusions and questions for discussion

59. This note presented an analysis of the link between structural transformation, Industry 4.0 and the potential impacts on inequality of these changes. Industry 4.0 has the potential to help improve the productive capacity of developing countries and contribute to their structural transformation. However, these new technologies should operate within a context of sound STI policies that support economic and social transformation before STI gaps across and within countries reach a tipping point and become irreversible.

60. Further, this note described how Industry 4.0 is currently characterized by a high degree of market concentration of leading firms in a few countries. This could result in measurable impacts on jobs, profits and the technological gap between firms and countries.

61. Consequently, STI policy that promotes the adoption and development of Industry 4.0 technologies should be properly aligned with other policy domains to support a widespread diffusion of the technology based on strong infrastructure and capabilities in countries, and placed suitably in an international context.

62. Also, STI policies should support an innovation environment that contributes to reducing inequality across different dimensions – among and within countries, across firms, across generations and between men and women. STI policy should also consider as one of its major concerns the provision of directionality to technological change, such as the emergence of Industry 4.0, to proactively prevent any negative outcomes of inequality. Finally, STI policy cannot be developed and implemented without consideration of its interactions with other policies, including redistributive policies, to address inequality.

63. The Investment, Enterprise and Development Commission may wish to discuss the following questions related to policy responses at all levels that may be relevant to step up

[53] United Nations, forthcoming, Science, technology and innovation for development, Report of the Secretary-General.

[54] IATT, 2018, *IATT Issues Brief on Science, Technology and innovation for SDGs [Sustainable Development Goals] Road Maps*; and E/2019/78.

current efforts in STI in an inclusive way in the context of Industry 4.0 and the Sustainable Development Goals:

(a) National innovation policy in general: What challenges, benefits and practical lessons can be identified from the adoption of policies and strategies for Industry 4.0 in the national context? Were there any distributional effects in terms of inequality within a country?

(b) Innovation policy in the global context: What global Industry 4.0 developments are likely to affect domestic firms and industries in terms of their national and international competitiveness? How can national STI policies on Industry 4.0 support or enable the development of new comparative advantages?

(c) Directionality of innovation policies: What is the experience of member States in designing and implementing innovation policies that foster the application of Industry 4.0 towards the creation of new or improved products and services that contribute to reducing inequalities? Are there any policies or projects aimed at solving regional or sectoral inequality in technological absorption, diffusion and deployment? How have the policies targeted inequalities? Do any of these policies, projects or initiatives target women, youth, people with special needs or other groups that face specific challenges?

(d) Policy measures to ensure that no one is left behind: What is the experience of member States with regard to adopting policies, projects or initiatives that mitigate the potential negative effects of Industry 4.0 on inequality? What lessons have been learned from policies designed to protect people affected by rapid changes in labour markets (for example, greater benefits for those whose jobs disappear, retraining programmes, federal job guarantees)? What is the role of redistributive policies aimed at ensuring that no one is left behind due to rapid technological change? How do these policies address the impact of Industry 4.0 on market concentration and the division of profits?

(e) How can international entities such as UNCTAD support improved STI policymaking and international cooperation network building to harness Industry 4.0 for structural transformation and inequality reduction?