United Nations E/CN.16/2020/2

# Economic and Social Council

Distr.: General
13 January 2020

Original: English

**Commission on Science and Technology for Development**
Twenty-third session
Geneva, 23–27 March 2020
Item 3 (a) of the provisional agenda

# Harnessing rapid technological change for inclusive and sustainable development

## Report of the Secretary-General

*Summary*

This report discusses how to harness rapid technological change for inclusive and sustainable development. It presents the concerns arising from rapid technological change that could affect inequalities and considers opportunities and innovative business models in contributing to inclusiveness and sustainability. The report highlights the role of appropriate science, technology and innovation policies that provide directionality to rapid technological change through a supportive enabling environment, skills development to foster innovation, with an emphasis on carefully scaling up businesses and technological foresight. The report presents examples of national policies and takes stock of regional, international and multi-stakeholder cooperation. It concludes with suggestions for Member States and the international community.

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# Introduction

1. At its twenty-second session in May 2019, held in Geneva, the Commission on Science and Technology for Development selected "Harnessing rapid technological change for inclusive and sustainable development" as one of its priority themes for the 2019–2020 intersessional period.

2. The secretariat of the Commission convened an intersessional panel from 7 to 8 November 2019 in Geneva, to contribute to a better understanding of this theme and to assist the Commission in its deliberations at its twenty-third session. This report is based on the issues paper on harnessing rapid technological change for inclusive and sustainable development prepared by the Commission secretariat,[1] the findings of the panel, country case studies contributed by Commission members, relevant literature and other sources.

3. This priority theme builds on one of the priority themes presented for consideration at the twenty-second session of the Commission, "The impact of rapid technological change on sustainable development",[2] in response to General Assembly resolutions 72/242 and 73/17.

4. During its twenty-second session, the Commission underscored that rapid technological change and frontier technologies bring enormous opportunities to accelerate progress towards the Sustainable Development Goals. At the same time, they also pose new challenges, as they could disrupt labour markets, exacerbate or create new inequalities and raise ethical questions. Enabling inclusive access to technology can support the development of new business models that contribute to inclusive and sustainable development. Science, technology and innovation policy also has a role in setting the direction of technological change to minimize its impact on inequality, as well as in addressing already existing inequalities through technology and innovation.

5. The Commission decided to focus its work during the current session on a set of digital frontier technologies such as artificial intelligence, big data and robotics.

# I. Technological change, sustainability and inclusiveness

6. Technological change is essential for economic growth and sustainable development, touching on all the Sustainable Development Goals.[3] However, two factors can reduce its potential benefits for the achievement of the 2030 Agenda for Sustainable Development. First, despite the recent rapid technological change in many frontier technologies such as artificial intelligence, biotechnology, nanotechnology and others, this change is not necessarily aligned with the achievement of the Sustainable Development Goals. The 2030 Agenda requires economic, social and environmental transformations that can only be achieved through breakthrough innovations that tackle difficult and intertwined social and developmental challenges. For example, the climate change mitigation pathways for limiting warming to 1.5° Celsius require innovations that reduce energy demand and agricultural emissions, decarbonize electricity and other fuels, and perform carbon dioxide removal with carbon storage on land or sequestration in geological reservoirs.[4] Rapid technological change is essential to deliver these transformations but it is not sufficient.

[1] The issues paper, presentations and contributions to the intersessional panel cited in this report are available at https://unctad.org/en/pages/MeetingDetails.aspx?meetingid=2232. All websites referred to in this report were accessed on 27 September 2019.

[2] See E/CN.16/2018/4 and E/CN.16/2019/2.

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

[4] Intergovernmental Panel on Climate Change, 2019, *Global Warming of 1.5°C: An Intergovernmental Panel on Climate Change Special Report on the Impacts of Global Warming of 1.5°C above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development and Efforts to Eradicate Poverty*, Geneva.

Because those who are left behind by less inclusive development patterns are also those who are more vulnerable to the consequences of environmentally non-sustainable economic practices, technological change and innovation must be directed towards the Sustainable Development Goals holistically, addressing all the dimensions of sustainable development.

7. Second, even when rapid technological change is aligned with the achievement of the Sustainable Development Goals, it can widen inequalities initially. The reason is that not everyone has access to the fruits of technological change at the same time. Existing inequalities limit the access to products and services that use frontier technologies, further increasing these inequalities or creating new ones. To harness rapid technological change for inclusive and sustainable development, Governments and other stakeholders need to ensure that the benefits of frontier technologies reach a majority of people, including the most vulnerable.

8. The following sections discuss the need to direct technological change towards sustainable development and to mitigate the potential negative impacts on inequalities. The latter focuses on five areas – automation, market concentration, biased design, unequal technology access and widening technological gaps – in which technological change and associated transformations might contribute to growing challenges, but to opportunities as well.

## A. Directing rapid technological change towards inclusive and sustainable development

9. Because the 2030 Agenda is intrinsically transformational, science, technology and innovation policy is key to giving directionality to the process of technological change to ensure that change is aligned with societal needs, including sustainability and the reduction of inequalities.[5] For example, Sustainable Development Goal targets, such as 6.4 on water use efficiency, 7.3 on energy efficiency, and 8.4 and 9.4 on resource efficiency, all require directed technological change.

10. In principle, from a user's perspective, recent technological advances could bring huge benefits that touch on all the Sustainable Development Goals. These technologies enable the fourth industrial revolution and smart manufacturing for economic development, improve crop and livestock agriculture, address intractable health challenges, promote social inclusion and expanded access to quality digital education, and so forth. However, policy directionality is necessary because the scale and ambition of the Sustainable Development Goals need to be addressed not by an innovation agenda that tries to find applications of frontier technologies that deal with the challenges posed by the Goals, but by targeted large-scale science, technology and innovation programmes for breakthrough technologies designed to address the Sustainable Development Goals in the first place.

11. A previous report of the Secretary-General entitled "New innovation approaches to support the implementation of the Sustainable Development Goals" (E/CN.16/2017/2) discussed at length ways to direct innovative activities towards the Sustainable Development Goals through mission-oriented innovation. It highlighted the role of State-funded programmes, initiatives led by philanthropic organizations, State investment bank mission-oriented finance programmes that create demand for new technologies and public–private initiatives such as the Global Alliance for Vaccines and Immunization.[6] An example of this mission-oriented approach applied to frontier technologies is the Energy Storage Partnership convened by the World Bank to foster international cooperation to adapt and develop energy storage solutions for developing countries. The partnership complements the World Bank's $1 billion battery storage investment programme to significantly scale up support to battery storage projects and raise an additional $1 billion in concessional finance.[7]

[5] UNCTAD, 2019a, *A Framework for Science, Technology and Innovation Policy Reviews: Harnessing Innovation for Sustainable Development* (United Nations publication, Geneva).

[6] See www.gavi.org/.

[7] See https://esmap.org/webpage/energy-storage-partnership-esp-factsheet.

12. However, an analysis of national strategies on frontier technologies shows that most of these strategies usually do not recognize the need and particular challenges in implementing these new technologies to address the Sustainable Development Goals.[8] For example, a majority of recent national strategies on artificial intelligence, big data and the Internet of things focuses on increasing industry competitiveness without taking the opportunity to create incentives for technological change in these areas towards addressing challenges relating to the achievement of the Sustainable Development Goals. Exceptions are the national strategies and international programmes on biotechnologies, which have focused on areas such as special programmes for disadvantaged social groups, including women; urban agriculture; healthy ageing; farmer and community innovation; food security; and drug resistance to tuberculosis.

13. Directing rapid technological change towards the Sustainable Development Goals presents many challenges for policymakers. A crucial challenge is that of setting priorities and identifying and defining appropriate missions (E/CN.16/2017/2). This is somewhat simpler in the case of directing the development of biotechnology towards health-related Sustainable Development Goals, given that this technology has been historically used in health, and the health-related targets outlined in the 2030 Agenda are well specified. For technologies such as artificial intelligence and the Internet of things, for which the application is virtually unlimited and could affect all Goals, it is more challenging to set priorities on the development of biotechnology. International cooperation could play an instrumental role in setting such priority areas and in directing rapid technological change in frontier technologies towards achieving the Sustainable Development Goals.

## B. Dealing proactively with the unintended consequences of technological change on inequalities

### 1. Automation of tasks and digitalization of economies

14. The impact of frontier technologies on labour markets could have consequences for income distribution. Frontier technologies contribute to shaping new sectors and new career options. On the other hand, some frontier technologies, for instance, artificial intelligence and robotics, could increase job polarization and wage inequality, particularly in developed countries. Ever more capable machines are taking over routine tasks. Those performing non-routine tasks that use complementary technologies, both in manual and cognitive jobs, as well as owners of capital, data and algorithms, stand to gain. Some estimates of the impact of automation on jobs suggest that almost 50 per cent of jobs in Europe and the United States of America are at risk in the coming decades as digital technologies increasingly perform routine tasks.[9] Others see a much more modest impact across occupations of an average below 10 per cent.[10]

15. Firms that provide services through digital platforms create new earning opportunities and may thereby reduce inequality. For tradable services, such as computer codes, medical diagnostics or paralegal assessments, anyone with Internet access and appropriate skills could join a global labour market.[11] Refugees and people from vulnerable communities that have received training in digital technologies through a project of the World Food Programme, Empowerment in Action, commonly known as EMPACT, found

[8] UNCTAD, forthcoming, *Technology and Innovation Report 2020*.

[9] For example, up to 47 per cent of jobs in the United States are at risk of being automated (CB Frey and M Osborne, 2016, The future of employment: How susceptible are jobs to computerization? *Technology Forecasting and Social Change*, 114:254–280). In the 28 countries of the European Union, the figure is 54 per cent on average (J Bowles, 2014, *The computerization of European jobs*, The Bruegel Institute).

[10] For example, across countries of the Organization for Economic Cooperation and Development (OECD), the average share of jobs at risk of being automated is 9 per cent. 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.

[11] See UNCTAD, 2017, *Information Economy Report 2017: Digitalization, Trade and Development* (United Nations publication, Sales No. E.17.II.D.8, New York and Geneva).

jobs as online freelancers, increasing their prospects for integration and financial self-reliance.[12]

16. High-skilled services (for instance, engineering, legal work, finance and health care) are also becoming tradable on a global scale. Technologies such as machine translation (removing the language barrier), telepresence and augmented reality applications (reducing the distance barrier) enable this process.[13] These developments put white-collar workers in developed and developing countries in direct competition, which contributes to weakening workers' bargaining power and diminishing their labour rights. These developments also affect traditional occupations in direct competition with the new services and products.

17. Thus, new jobs will be created in various sectors, although the net effect on the labour markets remains to be determined, particularly the impact across countries and through shifts in trade and specialization patterns. Action by Governments and other stakeholders should support a transition period that facilitates adaptation. Relevant policies relate to retraining, life-long learning and employment support mechanisms that could limit the risk of technological unemployment.

18. The distributional effects of innovation can also result from new products and services addressing previously unmet needs and improving welfare. For example, chatbots and virtual assistants can provide services online – which would otherwise not be available because of high labour requirements – and improve users' experience in dealing with businesses and Governments. The administration of Latvia improved access to its enterprise register and rural support service with a virtual assistant, and the Ministry of Foreign Affairs of Mexico introduced a chatbot, distributing information to Mexicans abroad.[14]

### 2. Market concentration

19. The economies of scale and scope and the networked nature of many platforms based on frontier technologies – for example, search engines, cloud computing and artificial intelligence services – enable winner-takes-all dynamics, leading to market concentration. While it is normal that innovative firms enjoy higher profits due to temporary monopolies, leading firms in frontier technologies may be able to develop strong positions by bundling their technology with additional products and services that enable them to exercise their market power more in the long term.[15] This is true especially for digital platforms. With rising user numbers, the platforms can extract more data. The resulting insights are used to surpass the competition and preserve a first-mover advantage. As the platforms expand their service offers, switching becomes more costly for the users.[16]

20. However, the position of these firms needs not be static. Robust competition policy has a role to play in reducing the potential adverse effects of excessive market domination of leading technology firms on further innovation. Disseminating innovations among firms can promote increasing efficiency through competition and the resulting incentives for process innovation. Governments and other stakeholders could support this process by creating programmes and mechanisms to disseminate the application of frontier technologies and the examples of successful business models. The Made Different: Enabling Factories of the Future programme (Belgium), the Digital Technologies project (Russian Federation) and the Small and Medium-sized Enterprises Capability Centre (Turkey) are examples of such programmes.[17]

[12] Contribution from the World Food Programme.

[13] R Baldwin, 2019, *The Globotics Upheaval: Globalization, Robotics and the Future of Work*, Weidenfeld and Nicolson, London.

[14] Contributions from the Governments of Latvia and Mexico.

[15] Contribution from the Economic and Social Commission for Asia and the Pacific (Economic and Social Commission for Asia and the Pacific, 2018, *Inequality in Asia and the Pacific in the Era of the 2030 Agenda for Sustainable Development* (United Nations publication, Sales No. E.18.II.F.13, Bangkok).

[16] UNCTAD, 2019b, *Digital Economy Report 2019: Value Creation and Capture – Implications for Developing Countries* (United Nations publication, Sales No. E.19.II.D.17, Geneva).

[17] Contributions from the Governments of Belgium, the Russian Federation and Turkey.

### 3. Biased design

21. The design and use of technology can perpetuate and increase inequalities. For example, the default female voice of digital assistants could preserve gender biases and the stereotype of women in subservient positions.[18] Technology built with men in mind reduces the benefit of products and services for women, such as in automotive voice recognition that reacts better to lower-pitched voices and in fitness trackers that underestimate predominantly female-associated activities such as housework.[19]

22. Further, artificial intelligence and machine learning are only as good as the data they are trained on. For example, an artificial intelligence system developed to assist in the recruitment of software engineers was found to penalize women's curricula vitae. This bias was not coded in the algorithm, but learned through the company's historical recruitment data that favoured men.[20] In another case, an artificial intelligence system to assist judges in improving sentencing, based on reoffending probabilities, was found to be biased against ethnic minorities.[21] Other cases have been reported in which the digitalization of welfare services and the mandatory use of digital channels to access social services, work, pensions, disability and health benefits – although potentially improving efficiency and transparency – punish those without digital access and skills. System glitches can leave people without access to benefits, to the point of life-or-death situations.[22]

23. The international community has a role to play in raising awareness of the private sector and other stakeholders about the unintended consequences of some of these frontier technologies that are becoming an integral part of personal, social and business interactions in many parts of the world. Developers need to build their capacity to identify the potential negative effects of their products on society and establish mechanisms to improve their research and development processes to avoid biased design. All stakeholders should pay attention to developing mechanisms that ensure that training data are free from biases, so that artificial intelligence applications do not replicate discriminations entailed in biased data.

### 4. Unequal access to new technologies

24. Unequal access to technology-enabled products and services can perpetuate inequalities. The availability of essential technological infrastructure, such as the Internet or electricity, is important to ensure access. Unequal access to support infrastructures is often correlated with geographical disparities in infrastructure, for example in rural and urban, mountainous or remote regions, and their affordability.

25. Access to digital infrastructure is critical, as digitalization and connectivity are enablers of frontier technologies. Since 2018, more than half of the world's population – more than 4 billion people – has been connected to the Internet. Another half is still disconnected and, consequently, out of direct reach of the benefits of digitally enabled innovations. Regional disparities remain: those without Internet connections make up less than 20 per cent of people in Europe, compared with over 70 per cent in Africa and more than 80 per cent in the least developed countries.[23]

26. Affordability also determines technology access. The cost of Internet access in developing countries and in the least developed countries has nearly halved since 2008 but remains high. Fixed broadband costs in the least developed countries are often prohibitive at around 54 per cent of gross national income per capita, in contrast to 1.4 per cent in

[18] EQUALS, 2019, I'd blush if I could: Closing gender divides in digital skills through education, United Nations Educational, Scientific and Cultural Organization, Paris.

[19] MB Nelson, LA Kaminsky, DC Dickin and AH Montoye, 2016, Validity of consumer-based physical activity monitors for specific activity types, *Medicine and Science in Sports and Exercise*, 48(8):1619–1628.

[20] See www.theverge.com/2018/10/10/17958784/ai-recruiting-tool-bias-amazon-report.

[21] See http://harvardmagazine.com/2019/01/artificial-intelligence-limitations.

[22] See www.theguardian.com/ technology/series/automating-poverty.

[23] International Telecommunication Union, 2019, International Telecommunication Union News, Measuring digital development: Facts and figures 2019, 5 November.

developed countries. Mobile Internet access is more affordable, costing 1 per cent of gross national income per capita in developed countries, 4.5 per cent in developing countries and 9.8 per cent in the least developed countries.[24] However, mobile Internet is not always sufficient to meet the data needs of frontier technologies.

27. Access to frontier technologies is also affected by personal factors, such as basic (digital) literacy, age and accessibility issues. Social factors that hinder the access of certain groups can also perpetuate inequality. For instance, in India, social norms can prevent girls and unmarried women in some villages from using mobile phones.[25]

28. Consequently, Governments and other stakeholders must address existing inequalities head-on rather than using measures that merely aim to curb the threat of rapid technological change, perpetuating inequalities. At the same time, emphasizing the positive uses of frontier technologies, especially those that address the Sustainable Development Goals for vulnerable and low-income groups, is important. For example, Latvia has introduced an artificial intelligence-based solution to diagnose cancer.[26]

## 5. Widening the technological gap

29. Frontier technologies are usually applied first and more intensely in industries and segments of value chains in which more industrialized economies have a comparative advantage, widening the technological gap.

30. This tendency risks perpetuating technological disparities between developed and developing countries. Less technologically advanced countries diversify their economies by emulating industries that already exist in more industrialized countries.[27] If the technological gap between firms in developed and developing countries is widened by the former's adoption of frontier technologies, then emulation by developing country firms becomes more challenging (TD/B/C.II/43). In addition, challenges may grow as technological advances make reshoring of production from less technologically advanced countries to industrialized countries economically feasible, and consequently, local production sites with new technologies replace offshore production using low labour costs.[28]

31. Also, within developed countries, the technological gap between frontier firms and other firms is increasing. This slows technological diffusion and enables frontier firms to capture bigger market shares. Thus, the technological gap contributes to inequality through direct (profits) and indirect (fewer good jobs) effects.

32. Inequality created by frontier technologies has a spatial dimension, in which high value added activities, especially in technology development, tend to cluster geographically in places such as Silicon Valley in the United States. This result is contrary to the idea that information and communications technologies (ICTs) would make geographical location irrelevant. Therefore, innovation policy leading to a concentration of innovative firms and skilled workers may need to reconsider how to address this issue to spread the benefits of innovation more evenly on a geographical scale – innovation policy always had a geographical dimension.

33. Governments and the international community should continue to promote international technological assessments and foresight exercises to better understand the impact of rapid technological change on inequality and for inclusive and sustainable development.

[24] International Telecommunication Union, 2019, ICT price baskets data, available at www.itu.int/en/ITU-D/Statistics/Pages/ICTprices/default.aspx.

[25] See www.independent.co.uk/news/world/asia/girls-and-unmarried-women-in-india-forbidden-from-using-mobile-phones-to-prevent-disturbance-in-a6888911.html.

[26] Contribution from the Government of Latvia.

[27] S Lall, 1992, Technological capabilities and industrialization, *World Development*, 20(2):165–186.

[28] UNCTAD, 2019b.

# II. The role of businesses in deploying frontier technology to support inclusiveness and sustainability

34. Frontier technologies contribute to inclusive and sustainable development through innovations that are economically viable, broadly accessible and harmless to the environment. Businesses are key in turning technological knowledge into practical and economically viable applications to solve human needs and are thus critical for harnessing frontier technologies for inclusive and sustainable development.

35. Frontier technologies, particularly in the digital field, play an important role in reshaping business models for inclusiveness. A growing number of digitally enabled businesses now aim to combine profit and purpose, explicitly targeting low-income consumers and giving them more choices through innovation.[29] They deliver profitably, while contributing to a better life for a broader number of people through their products and services and thus also contribute to the achievement of the Sustainable Development Goals (see E/CN.16/2017/2).

36. A new wave of innovations that are considered to be promising investments has emerged. According to market data from one venture fund, technology start-ups in Africa raised more than $1 billion in equity funding in 2018. Total foreign direct investment to African countries in the same year amounted to $46 billion.[30] Technology start-up funding consequently amounts to 2.5 per cent of overall capital inflows. Nevertheless, this inflow represents a growth of 108 per cent year on year.[31] Nine countries received funding of more than $10 million: Egypt, Ethiopia, Kenya, Malawi, Nigeria, Rwanda, Senegal, South Africa and the United Republic of Tanzania. In some of the largest recipients, business models have been developed that align with the Sustainable Development Goals, especially in the domain of financial inclusion, such as Tala from Kenya, which offers loans through a mobile application using non-traditional loan scoring (https://tala.co.ke/about/). Other vital areas for inclusive and sustainable development and achieving the Sustainable Development Goals still need to generate promising solutions. For example, education and health received only 2.7 and 1.5 per cent of all equity funding, respectively, whereas financial technology received much more.

37. Delivering on inclusive and sustainable development through businesses improves the financial sustainability of efforts to achieve the Sustainable Development Goals and lessens the financial burden on the Governments of developing countries. Innovations serving the poorest parts of society with a profit motivation could persist longer than some not-for-profit initiatives. However, inclusive business models are not restricted to for-profit models. They also include innovative organizational arrangements and delivery channels of public services without a profit objective, such as education and health, or social innovations, such as financial tools for the previously unbanked. Some of these new approaches were addressed in detail by the Commission at its twentieth session under the priority theme, “New innovation approaches to support the implementation of the Sustainable Development Goals” (E/CN.16/2017/2).

# III. Shaping rapid technological change to support inclusive and sustainable development

38. Science, technology and innovation policy can play a part in creating an enabling environment to facilitate the inclusive and sustainable application of frontier technologies by shaping the innovation environment, furthering skills development, scaling up businesses and employing technological foresight.

[29] CK Prahalad, 2006, *The Fortune at the Bottom of the Pyramid: Eradicating Poverty through Profits,* Pearson Education, Wharton School Publishing, United States.

[30] UNCTAD, 2019c, *World Investment Report 2019: Special Economic Zones* (United Nations publication, Sales No. E.19.II.D.12, Geneva).

[31] Partechpartners.com, 2019, 2018 was a monumental year for African tech [technology] start-ups, with US$1.163 billion raised in equity funding, a 108% YoY [year-on-year] growth.

## A. Shaping the enabling environment

39. There are policy implications that arise from the characteristics of the business models that are emerging as most relevant for frontier technologies, especially the importance of digitally enabled innovation, and the wider context of supporting frontier technologies for inclusive and sustainable development. However, without supporting science, technology and innovation policies, contributions from businesses models may not be as capable in supporting progress of the 2030 Agenda. This requires an appropriate enabling environment for the innovation system. National innovation systems are based on the "the network of public and private institutions whose activities and interactions initiate, import, modify and disseminate new technologies".[32] At the core of innovation systems are firms, in addition to research and education systems, Government, civil society and consumers (E/CN.16/2019/2).

40. Many countries have adopted strategies for the development of frontier technologies to guide the use, adoption, adaptation and development of these technologies, especially in the domain of digitalization. Examples include the federal and regional strategies for digitalization of Belgium (Digital Belgium, Industry 4.0, Digital Wallonia, bedigital.brussels), the National Digital Transformation System (Sin Digital) and the Digital Transformation Strategy (E-digital) of Brazil, the Digital Transformation Road Map of Turkey and the national Digital Economy programme of the Russian Federation. [33]

41. Science, technology and innovation policies for reducing inequalities should focus on strategies and mechanisms that create an enabling environment for new innovation approaches such as pro-poor, inclusive, below-the-radar, frugal, bottom-of-the-pyramid, grassroots, and market-oriented and social innovation approaches (see E/CN.16/2017/2).

42. Additionally, several countries have science, technology and innovation policies that aim to reduce the cost of vital technology-based services. For example, the Russian Federation has started pilots using domestic digital solutions to reduce the cost of public services related to paramedic and obstetrical stations, secondary schools, and fire and police stations.[34]

43. Since science, technology and innovation activities in some areas have spillover effects that benefit the whole society, science, technology and innovation policy could guide innovation using frontier technologies to increase social welfare. For example, in the Islamic Republic of Iran, the Government aims to balance the benefits and potential negative externalities of the new technologies by building advocacy coalitions in favour of innovation and sustainable development in the transportation sector.[35]

## B. Supporting innovation through skills development

44. Many of the aforementioned business models rely on mobile phones and digital platforms. To use technologies to their optimum, education is vital. Frontier technologies require sufficient literacy levels to navigate the platforms, as well as digital skills to be aware of risks associated with online financial or confidential transactions.[36]

45. Consequently, education plays an important role within science, technology and innovation policy instruments. Countries have developed various strategies, programmes and institutions designed to develop skills and raise interest in science, technology and innovation. For example, the strategy of the Digital Transformation Road Map of Turkey aims to train digital technology users through multiple channels. The Engineering High School of Riga Technical University, the All Girls Code initiative of Lebanon and the One

[32] C Freeman, 1987, *Technology Policy and Economic Performance: Lessons from Japan*, Pinter, London.

[33] Contributions from the Governments of Belgium, Brazil, the Russian Federation and Turkey.

[34] Contribution from the Government of the Russian Federation.

[35] Contribution from the Government of the Islamic Republic of Iran.

[36] UNCTAD, 2019a, *Building Digital Competencies to Benefit from Frontier Technologies* (United Nations publication, Geneva).

Million Arab Coders initiative of the United Arab Emirates prepare the developers of the future. Several initiatives advocate the fields of science, technology, engineering and mathematics (STEM). These include Technopolis (Belgium), S and T [Science and Technology] Caravan and Fabrication Laboratory for STEM at school (Thailand), Strategy for STEM Education (United States) and VET [Vocational Education and Training] Toolbox initiative (European Union).[37]

46. For innovators to define a problem, they often need to be exposed to it, which is why most innovators innovate for challenges that are close to home. Hence, the poor can be important innovators, inspired by their own experiences. Entrepreneurship training needs to reach all parts of society to ensure that innovators address diverse needs successfully. Examples of entrepreneurship training that can support the adoption of new technologies are the Digital Entrepreneurs Project of Brazil and several United States programmes targeting women, such as the Women Entrepreneurs Finance Initiative facility and the Women's Global Development and Prosperity Initiative.[38]

47. Further, learning on a societal level is required to address structural transformation and the dynamics arising from technological change. To avoid a mismatch between existing skills and those required for frontier technologies, the knowledge base of society must adapt to changes so as to support decent jobs and suitable innovation capabilities, leading to sustained and inclusive growth. Governments have an important role to play in sustaining these dynamics of structural transformation and transformation of knowledge.[39]

## C. Scaling up businesses

48. Weak financing mechanisms continue to impede the development of innovative products and services. Since many businesses at the bottom of the pyramid require a certain scale to be profitable, initial financing is important. Hence, growing inflows of equity funding are promising, but not sufficient. Specific financing must be found to cover the costs of adjustment and reconfiguration of the technology concerned to fit the new technological and economic environment. However, this problem is substantially greater for disruptive and inclusive business models. Traditional seed-stage technology investors are generally unwilling to invest in products aimed at markets they do not know, and where the duration to achieve profitability may be longer than in developed country markets. Conversely, impact investors targeting developing countries are generally unwilling to invest in risky, unproven technologies and business models, preferring instead to invest in companies employing proven technologies in local applications.

49. To facilitate the scaling up of business models using frontier technologies that address the Sustainable Development Goals, science, technology and innovation policy could provide incentives to attract private finance to innovative and inclusive business through matching funds, risk mitigation and other forms of support for private sector investments. Blended finance, that is, finance that combines a mix of public, private and development bank and donor financing, has become common in technology for development.[40]

50. Further, policies should foster the engagement of academia and civil society organizations with the private sector to support upscaling of solutions. For instance, science, technology and innovation policy could consider science parks, incubators, accelerators, innovation laboratories and marketplaces to incubate innovative ideas and foster innovation clusters, and to encourage experimentation and faster technology diffusion. For example, the publication entitled "*Perspectives of Brazilian Experts on*

[37] Contributions from the Governments of Belgium, Latvia, Thailand, Turkey, the United States and the Economic and Social Commission of Western Asia.

[38] Contributions from the Governments of Brazil and the United States.

[39] Contribution from I. Nübler, International Labour Organization, 2019–2020 intersessional panel presentation, Commission on Science and Technology for Development, available at https://unctad.org/en/pages/MeetingDetails.aspx?meetingid=2232.

[40] Contribution from A. Inbal, Pears Programme for Global Innovation, Jerusalem Institute for Policy Research.

*Advanced Manufacturing in Brazil*", collects expertise from industrial innovation specialists. It highlights the importance of new open laboratories for developing digital industry technologies for competitive manufacturing in Brazil.[41]

51. At the same time, science, technology and innovation policy should promote the scaling up and dissemination of successful innovations that emerge from these innovation hubs, to reduce the inequality created by the geographical concentration of technological capabilities.

### D. Technological foresight

52. The impact of frontier technologies remains uncertain. The extremely fast co-evolution of digital technologies, such as big data, the Internet of things, artificial intelligence, robotics and three-dimensional printing, and their accelerating interaction with technological change in other fields, such as biotechnology or material sciences, open an extremely broad range of new possibilities. But these factors also make it more difficult to predict the direction of change and increase the likelihood that some of that change may bring unintended consequences.

53. The importance of accessing the long-term scenarios of technology potential and proactively shaping policies to enable societies and policymakers to adapt to the changes created by the proliferation of new technologies, is increasingly acknowledged by Member States of the United Nations. The Economic and Social Council in resolution 2017/22 recognized that technology and assessment exercises could help policymakers and stakeholders in the implementation of the 2030 Agenda through the identification of challenges and opportunities that can be addressed strategically. In its most recent resolution on science, technology and innovation for development (resolution 2019/25), the Council encourages Governments to undertake systemic research for foresight exercises on new trends in science, technology and innovation and ICTs in their impact on development, particularly in the context of the 2030 Agenda, and to consider undertaking "strategic foresight initiatives on global and regional challenges at regular intervals and cooperate towards the establishment of a mapping system to review and share technology foresight outcomes".

54. Technological foresight and evaluation instruments can be used to better understand the technological paths and potential long-term social, economic and environmental impacts and to inform science, technology and innovation policy. For example, strategic actions contained in E-digital (Brazil) include assessing the potential economic and social impact of disruptive digital technologies and proposing policies that mitigate their negative effects and maximize positive results.[42]

## IV. International collaboration

55. The international community can support efforts to harness rapid technological change for inclusive and sustainable development that prevent such change from leading to widening divides, greater socioeconomic inequalities and environmental degradation.

### A. Research cooperation and science–policy interface

56. Research is a vital pillar for finding innovative solutions to achieve the Sustainable Development Goals. To expand the benefits of research, international cooperation is important, as it can combine cutting-edge research insights with the needs of local contexts.[43]

[41] Contribution from the Government of Brazil.
[42] Ibid.
[43] UNCTAD, 2018.

57. International research cooperation has expanded in recent years with networks that extend across borders, institutions and disciplines: the share of scientific papers with co-authors from several countries increased by 15 percentage points to 25 per cent between 1990 and 2011.[44] Additionally, international research outputs have a greater impact, in terms of citations, than other papers.[45] This expansion has been especially eased by the advances in digital technologies that make cooperation across distances easier and more rapid. However, international research collaboration still relies significantly on interpersonal relationships between researchers.

58. The increasingly important role of international research collaboration makes it more difficult for national policy alone to direct research towards specific targets. While international collaboration can be assisted by enhancing local capacities for knowledge absorption and ensuring ease of information- and data-sharing between collaborators, it is important to shape emergent global research collaborative networks, including in their interpersonal aspects. A cost-effective approach is funding research-related expenses such as travel, convening conferences and enabling training abroad.[46] South–South, North–South and triangular collaboration in research networks can also help improve access to research infrastructure and the cost–benefit ratio of investment in it.

59. Public foundational research remains vital in an international context to ensure that emerging technologies are developed for inclusiveness and sustainability. Mission-oriented research can contribute to directing innovation towards areas that lack solutions from market-oriented innovation (E/CN.16/2017/2).

60. For instance, the Horizon 2020 programme of the European Union incorporates this idea of research with a foundational purpose. The Enhanced European Innovation Council Pathfinder pilot offers grants to research consortiums from different European Union member States and associated countries to develop radically new technologies. Targeted call topics include, for example, artificial intelligence and zero-emission energy generation.[47] Responsible research and innovation in Horizon 2020 implies that the research process and outcomes should be aligned with society's needs and values and that the consequences thereof should be anticipated.[48]

61. The Government of Japan combines official development assistance with international research collaboration to promote science, technology and innovation for the achievement of the Sustainable Development Goals. With programmes such as the Cross-ministerial Strategic Innovation Promotion Programme and the Science and Technology Research Partnership for Sustainable Development, Japan translates research results into social implementation in developing countries.[49] The latter programme also aims to enhance research capacity in developing countries.

62. In Belgium, the Flemish Institute for Technological Research, has designed the Global Sustainable Technology and Innovation Conferences to bridge the gap between cutting-edge technological development and international science, technology and innovation policymaking.[50] It also provides informal support to the Technology Facilitation Mechanism of the United Nations for the implementation of the Sustainable Development Goals and the transition to less carbon- and resource-intensive, more resilient, economic and inclusive sustainable development models.[51]

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[44] CS Wagner, HW Park and L Leydesdorff, 2015, The continuing growth of global cooperation networks in research: A conundrum for national Governments, *PLOS [Public Library of Science] One*, 10(7):e0131816.

[45] W Glänzel and A Schubert, 2001, Double effort = double impact? A critical view at [sic] international co-authorship in chemistry, *Scientometrics*, 50:199–214.

[46] UNCTAD, 2018.

[47] European Commission, 2019, Enhanced European Innovation Council pilot, available at https://ec.europa.eu/research/eic/index.cfm?pg=funding.

[48] European Commission, 2019, Horizon 2020, Responsible research and innovation, available at https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation.

[49] Contribution from the Government of Japan.

[50] See https://2019.gstic.org/.

[51] Contribution from the Department of Economic and Social Affairs.

## B. Capacity-building

63. International cooperation contributes to shaping science, technology and innovation policies that can steer technological change towards sustainable development. For example, through international forums and mechanisms, Governments and other stakeholders can learn from each other's experiences and identify new ways for harnessing frontier technologies for sustainable development. The Commission on Science and Technology for Development[52] and the Multi-stakeholder Forum on Science, Technology and Innovation for the Sustainable Development Goals,[53] provide a forum for Member States to address the potential of new technologies in tackling societal challenges, the institutional changes needed to facilitate innovation in these areas and the international cooperation mechanisms that could be put in place to support these initiatives.

64. Several United Nations agencies have supported Member States in strengthening their capacities to develop and implement inclusive science, technology and innovation policies, such as the work of the Technology Bank for the Least Developed Countries, UNCTAD science, technology and innovation policy reviews, and the STEM and Gender Advancement project and Global Observatory of Science, Technology and Innovation Policy Instruments of the United Nations Educational, Scientific and Cultural Organization.[54] The United Nations also supports demonstrations programmes that disseminate best practices on the use of frontier technologies for inclusive and sustainable development, such as the Global Eco-Industrial Parks Programme of the United Nations Industrial Development Organization, as well as programmes that foster innovation in addressing specific Sustainable Development Goals, such as the youth entrepreneurship and innovation network on agricultural innovation of the Food and Agriculture Organization of the United Nations.[55]

65. Given the complexity and speed of technological change, such change could outpace the capacity of Governments to fully grasp its consequences. The Commission on Science and Technology for Development and the Technology Facilitation Mechanism, in response to General Assembly resolutions 72/242 and 73/17, are asked to consider, in a coordinated manner within their respective mandates, the impact of rapid technological change on sustainable development.[56]

66. As the focal point of the United Nations system for discussions on science, technology and innovation for development, the Commission has encouraged countries to undertake strategic foresight and technological assessment initiatives to better understand the socioeconomic and environmental implications of new and innovative technologies (E/RES/2019/25).

67. Another international cooperation activity that could be promoted in the context of the Commission is the creation of a network of social entrepreneurs for the dissemination of innovative business models using frontier technologies to address development issues. At the national level, Governments could promote a network of social businesses, entrepreneurs and practitioners. At the international level, the Commission could foster such a platform in collaboration with others.

## C. Official development assistance

68. Through technical cooperation programmes, international collaboration can support countries in building their national science, technology and innovation capacity, including in frontier technologies. Technical cooperation delivered through official development assistance is an important source of technical and financial support to developing countries.

[52] See E/2018/31–E/CN.16/2018/4 and E/2019/31–E/CN.16/2019/1.

[53] See E/HLPF/2019/6.

[54] Contribution from the United Nations Educational, Scientific and Cultural Organization.

[55] Contributions from the Food and Agricultural Organization of the United Nations and the United Nations Industrial Development Organization.

[56] See E/CN.16/2019/2 and E/HLPF/2019/6.

However, official development assistance to developing countries targeting some of the areas that contribute to building science, technology and innovation capacities has not increased over the past decade,[57] and in 2017, such assistance amounted to $4.8 billion. Of greater concern is that official development assistance to some of the countries with the lowest science, technology and innovation capabilities decreased slightly over this period for the least developed countries, from $0.9 billion in 2000 to $0.8 billion in 2017.[58]

69. Moreover, in 2017, less than 4 per cent the official development assistance commitments to developing countries were reported in sectors associated with science, technology and innovation. When considering the breakdown by sector, only 23 per cent of official development assistance was devoted to post-secondary education, 0.6 per cent to research and scientific institutions, 0.1 per cent to ICT, 0.06 per cent to import support of capital goods, 0.05 per cent to industrial development and 0.04 per cent to technological research and development.[59] The levels of official development assistance devoted to these sectors must increase. These are unquestionably key sectors for expanding the capacity of developing countries to harness science, technology and innovation for sustainable development, and they have long-lasting spillover effects in all areas of the Sustainable Development Goals.

# V. Suggestions for consideration by Member States and the Commission on Science and Technology for Development at its twenty-third session

70. Harnessing rapid technological change is critical for achieving inclusive and sustainable development. At the same time, rapid technological change has the potential to exacerbate existing inequalities within and among countries. Governments, the private sector and other civil society actors, as well as the international community, need to address key challenges head-on. International collaboration and national science, technology and innovation policies are needed to provide the enabling environment to steer rapid technological change towards improved inclusiveness, reduced inequalities and sustainability.

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

(a) Design and implement science, technology and innovation policies that provide directionality to rapid technological change towards inclusive and sustainable outcomes, including by creating an enabling ecosystem for innovative approaches for reducing inequalities, and through periodic reviews of national and regional priorities;

(b) Further national digital agendas that support closing digital divides in access and skills through appropriate ICT infrastructure and improving users' capabilities, especially among vulnerable groups, youths, and women and girls;

(c) Promote policies for skills development relevant to rapid technological change in terms of life-long learning, entrepreneurship training, upgrading of skills for innovators and capacity-building for researchers;

(d) Encourage decent work, by promoting decent jobs, facilitating labour mobility and supporting fair relationships between workers and employers;

(e) Foster innovation through entrepreneurship by strengthening funding mechanisms for innovation;

(f) Prepare for future changes by developing scenarios for rapid technological change for the workforce and the business sector;

[57] These include official development assistance commitments for post-secondary education, ICT, industrial development, technological research and development, research and scientific institutions, and import support of capital goods.

[58] UNCTAD calculations, based on data from the OECD Creditor Reporting System.

[59] Ibid.

(g) Promote the need for public sector innovation to render legal frameworks more responsive to rapid technological change;

(h) Apply a pragmatic, cross-cutting approach that allows Governments to prioritize innovations as a way of solving current societal challenges.

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

(a) Strengthen research cooperation and science–policy interfaces to ensure that frontier technologies are harnessed for inclusiveness and sustainability;

(b) Address the need for consistent normative frameworks and ethical principles relevant for rapid technological change for inclusive and sustainable development;

(c) Promote and develop international technology assessment and foresight mechanisms to help countries assess the challenges and opportunities of rapid technological change for inclusive growth;

(d) Share experiences on successful and innovative business models that harness rapid technological change to support inclusiveness and sustainability to facilitate their collaboration and dissemination.

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

(a) Share experiences on specific models for guiding Governments in designing science, technology and innovation policies for harnessing rapid technological change with detailed benchmarks;

(b) Encourage connecting discussions of science, technology and innovation policies with discussions on the future of work;

(c) Compile and share examples of innovative business models to support successful technological change;

(d) Develop synergies between the efforts by United Nations entities on science, technology and innovation for inclusive and sustainable development.