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# Foresight for digital development

## Report of the Secretary-General

*Executive summary*

This report discusses a number of digital developments, namely big data, the Internet of things, massive open online courses (MOOCs), three-dimensional printing and digital automation, and their potential long-term effects on the economy, society and the environment. Special focus is given to the role of technology foresight as a tool for policy planning in assessing the potential impact of these technologies on the society. Each chapter analyses the main features of these emerging technologies and their potential for sustainable development. The report highlights findings from relevant literature, experts' inputs and the deliberations by members of the Commission on Science and Technology for Development and other participants at the intersessional panel meeting. The report concludes with suggestions for consideration by national Governments and other relevant stakeholders.

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# Introduction

1. The Commission on Science and Technology for Development, at its eighteenth session held in May 2015, selected “Foresight for digital development” as one of its priority themes for the 2015–2016 intersessional period.

2. To contribute to a better understanding of this priority theme and to assist the Commission in its deliberations at its nineteenth session, the Commission secretariat convened a panel meeting in Budapest from 11 to 13 January 2016. This report is based on the findings of the intersessional panel, including the expert discussions held within the framework of the panel and inputs from experts in different areas.

3. Chapter I describes the context of the emerging technologies addressed in this report. Chapter II presents the main features of technology foresight and its potential as a tool for policymaking. Chapter III describes big data and the Internet of things and examines concerns and challenges related to these technologies. Chapter IV discusses the main features related to three-dimensional printing and its implications for sustainable development. Chapter V addresses digital automation and its implications for the future of work. Chapter VI discusses MOOCs, and their potential and considerations for contributing to sustainable development. Policy lessons are discussed in Chapter VII, while findings and suggestions are presented in Chapter VIII.

# I. Emerging digital developments

4. The report analyses a number of emerging digital developments, namely big data, the Internet of things, MOOCs, three-dimensional printing (also known as additive manufacturing) and digital automation, and their potential long-term effects on the economy, society, and the environment. These technologies and their impact deserve attention since they will likely disrupt and transform existing social, political, and economic norms, bringing opportunities and challenges for countries.[1]

5. This report has been prepared in response to the request of the Economic and Social Council to the Commission on Science and Technology for Development to act as a forum for strategic planning and to provide foresight about critical trends in science, technology and innovation in key sectors of the economy, and to draw attention to emerging and disruptive technologies.

6. The report builds on previous work of the Commission on two priority themes: “Information and communications technologies [ICTs] for inclusive social and economic development” (2013–2014), in which some of these trends were initially highlighted, and “Strategic foresight for the post-2015 development agenda” (2014–2015), in which the Commission identified strategic technology foresight as a useful tool for sustainable development.

## A. Access to information and communications technologies as a foundation for sustainable development and future digital trends

7. During the period spanning 2000–2015, technological advances combined with market liberalization have resulted in an explosive growth in mobile networks – both in

[1] Atlantic Council, 2013, Envisioning 2030: US strategy for the coming technology revolution, 9 December.

terms of their coverage and capabilities.[2] However, while this expansion of services has impacted a considerable portion of the world's population, access to affordable Internet remains limited for those populations that could potentially benefit the most – especially those living in the least developed countries (LDCs). For these populations, digital exclusion remains a reality. This highlights the importance of closing the digital divide that exists between and within countries.

8. There are policy opportunities and challenges related to Internet access.[3] Many developing countries are facing significant challenges for the expansion of their existing broadband infrastructure, such as the need for large capital investments, shortages of relevant skills, and hurdles relating to the spread of broadband services, for example lack of digital content in local languages. Overcoming these difficulties requires an enabling environment and supportive public policies.[4]

9. The new development framework – the 2030 Agenda for Sustainable Development – acknowledges that "the spread of ICT and global interconnectedness has great potential to accelerate human progress, to bridge the digital divide and to develop knowledge societies" (General Assembly, Transforming our world: The 2030 Agenda for Sustainable Development).[5] The Agenda includes 17 Sustainable Development Goals and 169 targets. The latter recognize the importance of ICTs in two ways. First, through explicitly defining ICTs-related targets on: education and scholarship (target 4.b), gender empowerment (target 5.b) and infrastructure for universal and affordable access to the Internet in LDCs (target 9.c). Second, through the inclusion of references to general technologies in which ICTs play an important role. For instance, ICTs are referred to in targets on economic growth, energy and water efficiencies, and climate change. Further, Goal 17 – "Strengthen the means of implementation and revitalize the global partnership for sustainable development" – calls to enhance the use of enabling technologies, in particular ICTs.[6] The cross-sectoral potential of ICTs to contribute to the Sustainable Development Goals underlines their importance as critical enablers for development.[7]

## II. Technology foresight

10. Technology foresight is the process of forecasting the evolution of technologies and their impact on society with a view towards developing policy within Government and/or strategy within firms.[8] There are different methodological approaches to technology foresight, including focus groups, the Delphi method, simulations, scenario-building and interviews.[9] In terms of sectoral participation, foresight exercises often consider multi-stakeholder participation and are conducted through open participatory processes.

11. Technology foresight has been widely applied as a policy instrument by Governments around the world during the last few decades. For example, Japan has been

[2] International Telecommunication Union, Information and communications technologies database.

[3] UNCTAD, 2015, *Internet Broadband for an Inclusive Digital Society*, Current Studies on Science, Technology and Innovation No. 11 (New York and Geneva, United Nations publication).

[4] Ibid.

[5] General Assembly Resolution 70/1.

[6] Chief Executives Board Joint Statement to the United Nations General Assembly on the Overall Review of the Implementation of World Summit on the Information Society Outcomes, 2015, available at http://www.ungis.org/ (accessed 23 February 2016).

[7] Ibid.

[8] O Saritas, 2014, Strategic foresight for the Post-2015 Development Agenda, Presentation at the Commission on Science and Technology for Development inter-sessional panel, 26–28 November.

[9] R Popper, 2008, How are foresight methods selected?, *Foresight*, 10(6): 62–89.

undertaking foresight at national level since the 1970s,[10] other European countries such as Germany, the Netherlands and the United Kingdom of Great Britain and Northern Ireland have engaged in foresight exercises since the 1980s,[11] and a growing number of developing countries have also undertaken technology foresight exercises.[12] In the current context of globalization, competition and fast technical change, foresight exercises can help developing countries to detect opportunities for future technological and productive specialization to catch up, leapfrog and forge ahead. Further, considering the potential to shape technological change and economic growth, foresight exercises should be designed and implemented in coherence with national development strategies, including industrial development.[13]

12. Many unanticipated aspects of the information society have emerged since the World Summits on the Information Society in 2003 and 2005, including Web 2.0, cloud computing, the pervasiveness of social media, extensive broadband networks and mass markets for mobile telephony and Internet. Opportunities as well as challenges have also been created with the new developments. Given the many dimensions in which emerging innovations in ICTs, including those addressed in this report, can present challenges and opportunities for development policies,[14] technology foresight exercises can help to anticipate forthcoming technological trends and enable proactive and adequate social responses.

# III. Big data and the Internet of things

13. Big data and the Internet of things are new digital developments that optimize existing business operations and make possible the creation of new products, services and even industries. Big data refers to the accumulation and analysis of greatly increased information resources, beyond the storage and analytical capacity of earlier hardware and software resources. It is made possible by increases in both data storage capacity and the range of available data sources.[15]

14. The Internet of things concerns the extension of connectivity beyond people and organizations to objects and devices used in daily life.[16] The Internet of things enables any object or device to be connected, respond to users' instructions and gather information that can be used in big data analysis.[17] Examples of devices associated with the Internet of things include sensor-based devices that monitor daily activities such as eating and sleeping; the control of home appliances using mobile phones; and sensor devices for improving agricultural productivity. In terms of coverage it is expected that the number of

[10] A Kameoka, Y Yokoo and T Kuwahara, 2004, A challenge of integrating technology foresight and assessment in industrial strategy development and policymaking, *Technological Forecasting and Social Change*, 71(6): 579–598.

[11] O Saritas, E Taymaz and T Tumer, 2006, Vision 2023: Turkey's national technology foresight programme – A contextualist description and analysis, ERC Working Papers in Economics 06/01 (Ankara, Economic Research Center).

[12] C Pietrobelli and F Puppato, 2015, Technology foresight and industrial strategy in developing countries, United Nations University–MERIT Working Paper Series 2015-016 (Maastricht, United Nations University–MERIT).

[13] Ibid.

[14] UNCTAD, 2015, *Implementing WSIS Outcomes: A Ten-year Review* (New York and Geneva, United Nations publication).

[15] Commission on Science and Technology for Development, 2014, Information and communications technologies for inclusive social and economic development, Report of the Secretary-General, p.8.

[16] See footnote 14, p.78.

[17] Ibid.

devices available will rise from 15 billion in 2015 to 50 billion by 2020.[18] The Internet of things market, currently valued at $655.8 billion, should reach $1.7 trillion in 2020 and be valued at between $3.9 trillion and $11.1 trillion by 2025.[19]

## A. Big data, the Internet of things and sustainable development

15. Big data and the Internet of things can contribute to achieving the Sustainable Development Goals, especially in the current context of near ubiquity of the Internet. These new technologies can contribute to manage and help to address critical issues at the global, regional, national and local levels. This section discusses potential uses and examples of these technologies in enterprise development, health, agriculture, energy and water.

16. Big data and the Internet of things may help to foster enterprise development. These technologies enable business to create personalized, fine-grained analyses of potential and current customers, improve user experience, and could potentially address inefficiencies in manufacturing and related processes. For example, the first microinsurance product in the world to be fully distributed and implemented over a mobile phone network was deployed in Africa and enabled by big data on climate and crop trends.[20]

17. Healthcare could potentially be improved if treatments were personalized, clinical data were collected beyond the occasional patient–doctor visit, disease progression were detected earlier and proactively treated (at the individual and community levels) and more effective cures were found for an array of intractable conditions. In particular, mapping data can help support response to disease outbreaks.[21] For instance, during a typhoid outbreak, the Ministry of Health of Uganda used mapping data applications to facilitate decision-making on the allocation of medicine and mobilization of health teams.[22]

18. Big data and the Internet of things are also creating new possibilities in agriculture (including food security). For instance, the Indian start-up CropIn provides analytics and software solutions for crop management. This company has developed a vegetation index using satellite imagery that ultimately provides decision support to farmers to help to ensure crop health (see box).

**Big data for agriculture in India**

The company CropIn was created to provide software solutions and analytics for crop management. Today, customers of this customized cloud application are large companies that have invested in food processing and agriculture and have had to depend heavily on their field staff to connect with farmers. The CropIn application tags crops and monitors their development until the harvest. The system, when fed with information pertaining to sowing time and seed type, provides crop development information at various stages of production. CropIn is used by 40 companies and benefits approximately 100,000 farmers across 15 states in India.[23]

[18] World Economic Forum and INSEAD, 2012, *The Global Information Technology Report 2012: Living in a Hyperconnected World* (Geneva, World Economic Forum), pp. 171–318.

[19] J Manyika, M Chui, J Woetzel, R Dobbs and J Bughin, 2015, The Internet of things: Mapping the value beyond the hype (McKinsey Global Institute), p.7.

[20] International Finance Corporation, 2015, Kilmo Salama – Index-based agriculture insurance: A product design case study (Washington, D.C.).

[21] J Manyika, M Chui, B Brown, J Bughin, R Dobbs, C Roxburgh and AH Byers, 2015, Big data: The next frontier for innovation, competition, and productivity (McKinsey Global Institute).

[22] United Nations Global Pulse, 2015, Data visualization and interactive mapping to support response to disease outbreak, Global Pulse Project Series No. 20.

[23] P Vikram Singh, 2015, The start-up revolution: Smart solutions for social good, *Governance Now*, 17 August.

19. Reducing energy consumption for sustainability as well as ensuring effective and efficient management of energy distribution in an increasingly urbanized world remains a challenge. Balancing energy demand and supply can be better achieved with the use of big data technologies. Smart grids can increase the role of renewable sources in energy distribution and production by allowing households equipped with solar panels or wind turbines to feed surplus energy back into the electricity grid. The real-time information provided by smart grids helps utility companies to improve their responses to demand changes, power supply costs and emissions, as well as to avert major power outages.[24] For instance, Zenatix, a Delhi-based start-up, deploys smart meters and temperature sensors to help households and offices reduce energy consumption through message-based alerts. One successful example of the company's impact is saving the Indraprastha Institute of Information Technology in Delhi close to $30,000 annually in energy consumption costs.[25]

20. The production and efficient distribution of water, especially in urban areas, is a perennial challenge for national, regional and local governments. Devices associated with the Internet of things, such as sensors, meters, and mobile phones, can be tapped for smarter water management, as in the example of a wireless sensor network to monitor and study the water quality in Bangladesh.

21. Collecting and measuring development indicators will be key to monitoring the progress towards achieving the Sustainable Development Goals. In this context, stakeholders, including international organizations, academics and firms are exploring how big data can contribute to Goal-monitoring activities.[26] For instance, a study carried out by the United Nations World Food Programme used mobile data to assess food security. The results showed that airtime could serve as a proxy indicator for marketplace food expenditures.[27] However, to transform big data into actionable information to monitor development progress there are specific requirements in terms of skill sets and technologies, aside from getting access to the right data sets.[28] Additionally, attention must be given to the countries that are producing less data and/or have less capacity in data analytics, such as LDCs, to avoid adding new facets to the digital divide.[29]

22. Further, big data and Internet of things sensors can be used for research and development. These technologies enable researchers to analyse and discover patterns of scientific data that have hitherto been beyond their reach. There are many areas where these capacities are extremely relevant such as in meteorological forecasting and understanding the working of the human brain. However, big data and the Internet of things also pose challenges to science. Some of these are related to (a) the facilitation of access to publicly funded data; (b) the protection of data privacy; (c) the challenge of ensuring that the research opportunities offered by big data and the Internet of things are globally available, especially in LDCs.[30]

23. Many big data technologies and artificial intelligence algorithms are built on technology with open access licences. This makes them freely available for use, sharing,

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[24] UNCTAD, 2015, *Science, Technology and Innovation for Sustainable Urbanization*, UNCTAD Current Studies on Science, Technology and Innovation No. 10 (New York and Geneva, United Nations publication).

[25] V Dora, 2015, Will energy and water challenges propel an IoT wave in India ?, *Your Story*, 20 July.

[26] For example, the work of the United Nations Statistical Commission and Global Pulse.

[27] United Nations Global Pulse, 2015, *2014 Annual Report*.

[28] United Nations Global Pulse, 2013, Big data for development: A primer, p.7.

[29] Ibid, p. 6.

[30] International Council for Science, InterAcademy Partnership, World Academy of Sciences and the International Social Science Council, 2015, *Open Data in a Big Data World: An International Accord*. Abbreviated version available at http://www.icsu.org/science-international/accord/open-data-in-a-big-data-world-short (accessed 23 February 2016).

modification and adaptation. It also creates opportunities for local and pro-poor local innovation adapted to local needs and markets. By using open access licences, local colleges and universities could develop adaptations of big data technologies and machine learning algorithms, targeting them for domestic challenges. However, to work with and to innovate using these technologies citizens need to have the appropriate skills (for instance, being able to perform big data analytics and visualization, requiring mathematics and computer skills).[31] This underlines the importance of capacity-building so that advantage may be taken of these new technologies.

24. Further, the emergence of small-scale entrepreneurs taking advantage of these and other technologies, such as three-dimensional printing, has led to the emergence of a new "maker movement". It has been argued that this trend has the potential to change the nature of who the producers are in the supply chain, making big data even more valuable.[32] However, there are concerns about the economic potential of the maker movements. These are related to entrepreneurs' capacity to accumulate the necessary knowledge required to introduce products that can compete with proficient design teams and manufacturing organizations.[33]

## B. Concerns and challenges related to big data and the Internet of things

25. The increasing development and application of big data and the Internet of things has raised concerns regarding the specific issues related to the threats associated with these digital technologies that can affect citizens' rights. These include Internet access, privacy, data ownership, market concentration and security frameworks, among others. Further understanding of the implications of these issues for societies can help policymakers to address them appropriately.

26. Big data analysis is frequently used to predict what will happen but not why. This means that the data are largely used to identify correlation and not to analyse causality. As people perceive the world as cause and effect, correlational conclusions from big data may be used to support faulty causal assumptions. This could lead to incorrect inferences and conclusions concerning actions to take and the system that is being measured.[34] This means that causality issues need to be considered when using big data analysis. Further, it is important to recognize that the potential benefits of big data and the Internet of things are not defined by the amount of information available but by our ability to understand those data to obtain useful insights. This point is often misunderstood and could lead to inaccurate conclusions.

27. The growing deployment and use of big data and the Internet of things can create a wide variety of employment. For instance, estimations for the United States of America report the existence of about 500,000 big data jobs in 2014 (big data jobs were defined as occupations requiring big data skills, such as data analytics or knowledge of big data programmes).[35] Countries' potential for active and competitive participation in global markets depends, among other factors, on their ability to offer a well-trained workforce able to understand and create value from the unprecedented flood of data created by these innovations. Some of the relevant occupations that are related to big data and the Internet of

[31] World Economic Forum, 2016, The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution (Geneva).

[32] C Anderson, 2012, *Makers: The New Industrial Revolution* (New York, Crown Business).

[33] A Jackson, 2014, Makers: The new industrial revolution, *Journal of Design History*, 27(3): 311–312.

[34] V Mayer-Schönberger and KN Cukier, 2013, *Big Data : A Revolution That Will Transform How We Live, Work, and Think* (Boston, Houghton Mifflin Harcourt), p. 163.

[35] M Mandel, 2014, Where are the big data jobs? (Washington, D.C., Progressive Policy Institute).

things are mathematics, computing and engineering.[36] In addition to a well-trained work force, effective applications of the Internet of things and big data will require a whole array of supportive infrastructure and enabling policy frameworks, such as cloud computing resources and standards of interoperability.

# IV. Three-dimensional printing

28. Three-dimensional printing involves creating physical products by iteratively layering the desired material to produce a three-dimensional structure.[37] It represents a change in the way of production by incorporating the "ability to turn data into things and things into data".[38]

29. Although three-dimensional printing was invented about three decades ago, due to significant cost reductions along with complementary developments in computer-aided design, the Internet, new materials for manufacturing and cloud computing, it has now become a viable technology for global manufacturers. Estimates show that the three-dimensional printing market is growing significantly and at a rapid pace both in developed and developing countries.[39]

## A. Three-dimensional printing and sustainable development

30. Three-dimensional printing could represent an opportunity for countries that do not have significant manufacturing capability and rely on massive imports of consumer goods. Three-dimensional printing has applications in a range of areas relevant for sustainable development, including enterprise development, environmental sustainability, housing and construction, and education.

31. In the area of enterprise development, especially in the manufacturing sector, three-dimensional printing has the ability to offer mass customization: engage in large production without high fixed-cost capital investments and at a lower variable cost than traditional methods; speed production due to shorter design, process, and production cycles; simplify the supply chain due to products being produced closer to the point of demand and with much less inventory.[40] Additionally, three-dimensional printing could potentially facilitate local innovation because of the simplification of the process and chain of production. Three-dimensional printing also offers potential for waste reduction since unused material is reused in successive printing.

32. In terms of environmental sustainability, three-dimensional printing technologies could potentially contribute to the decoupling of economic growth from greenhouse gas emissions and wasteful resource use if it were applicable to larger production volumes in consumer products or automotive manufacturing.[41]

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[36] See footnote 31.

[37] D Cohen, K George and C Shaw, 2015, Are you ready for 3-D printing?, *McKinsey Quarterly*, February.

[38] A.T. Kearney Inc., 2015, *3D Printing: A Manufacturing Revolution*, available at https://www.atkearney.com/documents/10192/5992684/3D+Printing+A+Manufacturing+Revolution.pdf/bf8f5c00-69c4-4909-858a-423e3b94bba3 (accessed 25 February 2016).

[39] Wohlers Associates, 2014, *Wohlers Report 2014: 3D Printing and Additive Manufacturing State of the Industry Annual Worldwide Progress Report* (Fort Collins).

[40] See footnote 38.

[41] M Gebler, AJM Schoot Uiterkamp and C Visser, 2014, A global sustainability perspective on 3D printing technologies, *Energy Policy*, 74: 158–167.

33. In the construction sector, three-dimensional printing prototypes have been used to inexpensively and quickly construct buildings in demonstration experiments across the world.[42] This technology may contribute to address challenges related to the provision of cost-effective and sustainable housing. The advantages of three-dimensional printing in construction include more accurate and faster construction of buildings as well as reduced labour costs, waste generation and health and safety risks. Lastly, in the education sector three-dimensional printing can contribute to innovative learning as abstract concepts are printed into physical three-dimensional models that aid student understanding.

## B. Concerns and challenges related to three-dimensional printing

34. Although three-dimensional printing can potentially contribute to economic diversification, reduce carbon emissions and facilitate innovative learning, as well as other sectoral and cross-sectoral applications, several issues need to be considered to exploit the technology's potential while minimizing its risks.

35. First, the wide deployment of this technology may impact employment patterns, especially in manufacturing sectors. If three-dimensional printing matures to a point where it could disrupt traditional manufacturing, it may potentially affect the demand for factory workers in countries with strong manufacturing industries.[43] Further research is needed to examine the potential impact on labour markets, especially in developing countries and LDCs.

36. Second, the potential deployment of three-dimensional printing in production processes underlines the need to upgrade the skills of the workforce to provide skilled technicians and specialists that can create and manage advanced and automated production systems.[44]

37. Third, three-dimensional printing could influence the trade of goods. This is because of the impact that three-dimensional printing can produce on the simplification of the supply chain, and which could mean that the trade of goods is replaced by transmission of data.[45] However, there are technical and cost considerations if three-dimensional printing is to go beyond its current prototyping role to support production in manufacturing global chains.[46]

38. Fourth, three-dimensional printers also have negative environmental implications. These include a tendency to consume more electrical energy than other forms of manufacturing (for example, compared to injection moulding), unhealthy air emissions (especially in home environments) and an increased reliance on plastics.[47] Therefore, if three-dimensional printing is to contribute to more sustainable development, concerted efforts are required to innovate so as to maximize the potential environmental benefits and minimize the associated environmental costs.

39. Fifth, three-dimensional printing could raise issues of intellectual property, data privacy and protection, and cybercrime that may need to be considered by policy makers. In

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[42] For an example of three-dimensional printed homes built in China, see http://www.ibtimes.co.uk/china-recycled-concrete-houses-3d-printed-24-hours-1445981 (accessed 23 February 2016).

[43] J Lanier, 2013, *Who Owns the Future?* (New York, Simon & Schuster).

[44] See footnote 31.

[45] Fung Global Institute, Nanyang Technological University and World Trade Organization, 2013, *Global Value Chains in a Changing World* (Geneva, World Trade Organization).

[46] See footnote 38.

[47] L Gilpin, 2014, The dark side of 3D printing: 10 things to watch, *TechRepublic*, 5 March.

particular, this technology could have a negative impact on producers of physical products. This is because it is unclear whether the free sharing of three-dimensional models on the Internet will follow a path similar to that of digital music witnessed over the past decade. Also, three-dimensional printing may pose threats that will need to be addressed with respect to data sharing and the printing of harmful and dangerous objects.

# V. Digital automation and the future of work

40. It was previously thought that there was a division between human and digital labour, with humans focused on tasks that cannot be reduced to rules or algorithms and computers focused on information-processing tasks with well-defined rules.[48] Following recent advances in technology, however, a broader range of non-routine tasks are now becoming equally automatable.[49]

41. Digital automation is characterized by the ability of computers to increasingly take over tasks related to cognitive and not just physical work.[50] The defining features of recent digital automation are that (a) cognitive and not just physical tasks can be completed by computers; (b) jobs are destroyed at a faster rate than they are being created.[51] Automation of work historically and in contemporary times has had significant implications for government policy on employment, labour markets and overall economic growth.

## A. Implications of digital automation for employment

42. Optimistically, digital automation can free workers to pursue more creative and interesting work tasks as well as cultural activities, relegating more predictable, routine activities to machines.[52] However, since automation increases the productivity of workers and can increase the scale of operations at marginal cost, it can eliminate the need for workers. For example, some argue that driverless vehicles will eliminate the need for taxi, bus and truck drivers and that nurses and care workers could have their jobs replaced by personal care robots.[53]

43. In terms of potential effects of automation, recent research using data from the United States has shown that approximately 47 per cent of total employment in that country is at risk of being computerized. Specifically, United States workers in transportation, logistics, office and administrative support are the most at risk. Also, many service workers also have jobs highly susceptible to computerization. Further, there is evidence that wages and educational attainment are negatively correlated with the probability of

[48] E Brynjolfsson and A McAfee, 2014, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* (New York, Norton).

[49] C Benedikt Frey, MA Osborne and C Holmes, 2016, Technology at work v2.0: The future is not what it used to be (Oxford Martin Institute and Citi), p.11.

[50] DH Autor, 2015, Why are there still so many jobs? The history and future of workplace automation, *The Journal of Economic Perspectives*, 29(3): 3–30.

[51] See footnote 48.

[52] UNCTAD, 2016, Harnessing emerging technological breakthroughs for the 2030 Agenda for Sustainable Development, Policy Brief No. 45.

[53] See footnote 48.

computerization.[54] It is predicted that there will be a further depletion of middle-skill jobs in the United States context.[55]

44. Increasing automation could trigger a cycle of stratified job displacement, potentially leading to widening inequalities and welfare reduction.[56] Work can be divided into routine versus non-routine and manual versus cognitive. Work tasks that are routine – meaning those for which a computer can be given instructions on how to replicate the tasks – are most amenable to digital automation, regardless of whether those tasks are manual (for example, part of assembly line operations) or cognitive (for example, routine data entry into a computer database).

45. This increasing stratified job displacement is known as job polarization: a collapse in demand for middle-skill jobs, while non-routine cognitive jobs (such as financial analysis) and non-routine manual jobs (like hairdressing) have held up relatively well.[57] The reason that non-routine manual jobs have held up well is that it is currently very difficult for a robot to mimic the dexterity and flexibility of human motion. Non-routine cognitive jobs are also not easy to routinize as they require levels of creativity and non-obvious cognitive tasks that are presently difficult to express as computer algorithms. But jobs in between these two extremes represent the middle-skills jobs that are disappearing, polarizing the remaining jobs that exist into non-routine manual jobs and non-routine cognitive jobs. By contrast, occupations in which computers and human cognitive abilities complement each other strongly, such as those related to non-routine tasks, can better resist automation processes. Further, it has been found that perception and manipulation, creative and social intelligence are tasks less likely to be automated.[58]

46. Additionally, automation can affect women and men differently. Women constitute low numbers in the science, technology, engineering and mathematics job families and therefore they may not be able to take advantage of the increased demand for workers with skills in these areas. A recent survey among 13 major developed and emerging economies revealed that female employment is concentrated in low-growth or declining occupations such as sales, business and clerical. At the same time, women are also less represented in sectors in which automation is expected to displace jobs such as manufacturing and construction. The projections based on the survey revealed that that the burden of expected job losses due to disruptive technological change falls almost equally on women and men in these areas.[59]

## B. Concerns and challenges related to automation

47. Digital automation can potentially improve workplace productivity and the scale of operations. This could benefit workers by relegating more predictable, routine activities to robots, and could amplify the comparative advantage of workers supplying problem-solving skills, adaptability and creativity. However, automation could potentially reduce the

[54] C Benedikt Frey and MA Osborne, 2013, The future of employment: How susceptible are jobs to computerization? (Oxford Martin School), pp. 44–45.

[55] Based on an approach that classifies jobs based on education and training levels, “middle-skill” jobs are those that generally require some education and training beyond high school but less than a bachelor’s degree: HJ Holzer and RI Lerman, 2009, The future of middle-skill jobs, Center on Children and Families Briefs No. 41 (Brookings), p. 1.

[56] See footnote 52.

[57] See footnote 48.

[58] See footnote 49.

[59] See footnote 44.

number of jobs available in occupations involving routine tasks and lead to a change in the composition of employment as well as job functions across sectors.[60]

48. Digital automation could have serious implications for employment prospects, especially in developing countries that rely on low-cost labour as a competitive advantage. These countries are likely to be most affected by digital automation in the coming years because, if labour can be replaced by robots and other automation, the low wage competitive advantage will largely disappear. In this regard, a recent report[61] has estimated that two thirds of all jobs could be susceptible to automation in developing countries in coming decades. However, the report also underscores that large-scale net job destruction due to automation should not be a concern for most developing countries in the short term. This is because of two reasons: new jobs and new tasks in existing occupations are created; and machines and digital technology are yet to become perfect or even good substitutes for many tasks.

49. Countries can help to mitigate automation's potential negative impacts by providing the education and training needed to respond to the demands of their labour markets.[62] Foresight could be a useful tool to predict how many people will be displaced by computers and in which sectors.[63] These employment implications should be investigated and fed into national policy planning for economic development, including labour markets, education and training policies, and industrial policy. If some sectors are particularly affected, policymakers can proactively shape labour markets and educational policy to respond to such challenges, in accordance with national development goals.

# VI. Massive open online courses and digital learning

50. Massive open online courses are online courses that allow for open access and participation through the World Wide Web and that can contribute to e-learning.[64] In addition to online video lectures, MOOCs also offer additional features such as online social sharing, interactive learning methods, and community teaching assistants that help moderating the discussion forums. Also, due to the digital nature of the educational content delivery, MOOCs allow tracking of the activities and performance of students.

## A. Massive open online courses and sustainable development

51. Massive open online courses could contribute to achieving Sustainable Development Goal 4 – "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all". MOOCs could potentially deliver mass education at low cost.[65] MOOCs have the potential to revolutionize the delivery of education, especially in resource-poor regions. This has economic and social implications for reducing the cost of

[60] See footnote 50.
[61] World Bank, 2016, *World Development Report 2016: Digital Dividends* (Washington, D.C.).
[62] See footnote 50.
[63] One illustrative example is a recent technology foresight exercise conducted in Singapore on automation and the future of employment. See Centre for Strategic Futures, 2015, *Foresight*, Prime Minister's Office, available at http://www.csf.gov.sg (accessed 24 February 2016).
[64] Another e-learning initiative to support open learning and education is Open Educational Resources: for more information see UNESCO, 2015, *A Basic Guide to Open Educational Resources (OER)*, available at http://unesdoc.unesco.org/images/0021/002158/215804e.pdf (accessed 24 February 2016).
[65] Presentation by M Sharples at the Commission on Science and Technology for Development inter-sessional panel meeting, 12 January 2016.

scaling up education and making high-quality educational content available to the underserved.

52. However, there are a variety of factors that may reduce the potential access and use of MOOCs. Some of these are related to infrastructure access and to the content of the educational material. In terms of infrastructure, participation in MOOCs requires users to have access to a reliable Internet connection, including upgraded software and hardware. This means that students from less-interconnected regions as well as rural areas lacking Internet and/or electricity infrastructure would not benefit from MOOCs.[66] This underscores the importance of reducing the digital divide as a first step so that citizens may take advantage of emerging ICT technologies.

53. In relation to content, issues of language as well as relevance of local content are among those that can hinder the potential use of MOOCs. In most cases the courses and material available through MOOCs are offered in English.[67] This could limit the potential of deployment of these e-learning tools to people from non-English-speaking countries. Further, the content provided by MOOCs, which is often standardized, may not be relevant or suitable for local context and educational needs and priorities.

54. Digital learning technologies such as MOOCs do not guarantee improved educational outcomes, and only through experimentation, monitoring and evaluation can its impact be assessed. MOOCs and other e-learning technologies should be designed and implemented in response to educational needs. Also, when analysing the sustainability and scaling up of e-learning projects, the educational goals as well as pedagogical approaches appropriate for a specific country or region need to considered.

# VII. Policy lessons

55. This chapter draws on thematic group discussions during the Commission on Science and Technology for Development intersessional panel meeting in January 2016 in Budapest, and on research carried out during the preparation of this report. The discussions addressed the impact of the emerging technologies considered in this report in the context of the Sustainable Development Goals. Against this background, three policy lessons have been identified.

## A. The basic requirements to take advantage of information and communications technologies are still pertinent

56. There are substantial differences when comparing the context in which new digital technologies are created today with those created a decade ago. New technologies are being developed in an environment shaped by the pervasiveness of digital technologies due to the growing ubiquity of mobile phones and Internet access. Also, they are emerging in a global context that has recently witnessed the agreement on the Sustainable Development Goals. Despite these differences, both old and emerging technologies share some commonalities in relation to the opportunities they offer and challenges they pose for countries and societies. This underscores the importance of continuing to address the fundamentals of development policy (such as access to energy, health, and investment and skills) and to draw on lessons and experiences from the past.

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[66] J Hansen and J Reich, 2015, Democratizing education? Examining access and usage patterns in massive open online courses, *Science*, 350(6265): 1245–1248.

[67] B Moser-Mercer, 2014, MOOCs in fragile contexts, in Proceedings of the European MOOCs Stakeholders Summit 2014, Lausanne, 10–12 February.

57. It is important to acknowledge and understand that the application of digital technologies can produce negative effects on social inclusion and can lead to inequality. For instance, big data and related digital technologies may potentially widen gaps between citizens. These gaps can occur between countries – with developing countries and LDCs falling behind even more – and also within countries, because of gender, race, geographical location and other factors.

## B. Local context and skills are fundamental to maximize the benefits of information and communications technologies

58. The development and implementation of emerging technologies should respond to local needs and drive innovation. New technologies contribute to sustainable development when they take into account the socioeconomic and political context of countries and include pro-poor, inclusive and people-centred considerations.

59. Local capacities are essential to ensure that countries benefit from new digital technologies while minimizing their negative impacts. This emphasizes the need for concerted efforts from all stakeholders to proactively adapt to the changes in the skill-sets demands of labour markets.

## C. Regulatory frameworks need to be adapted to respond to new challenges produced by emerging technologies

60. Emerging technologies not only create development opportunities but also produce challenges. These are related to data protection, sharing and stewardship, and need to be addressed by policymakers. Also, emerging technologies can pose new challenges in terms of citizens' rights and power balance when considering how the property of data is distributed among stakeholders. These may include loss of privacy, new (corporate) power structures that threaten consumer protection, and dependence on specific digital technologies, among others.

61. Further, new digital technologies enable participatory governance in ways previously unimaginable. However, it requires an engaged civil society as well as Governments that prioritize these types of interactions and can effectively harness such digital technologies.

## D. Institutionalizing technology foresight can help policymaking

62. Foresight can help identify technological developments and their economic and social impact. However, its most significant feature is that – when implemented in coherence with public policies – it can help shaping the future in a desirable way that allows maximizing the benefits of technologies while mitigating risks.

63. Foresight depends on the level of analysis, with different implications for local, regional or global concerns. The key challenge is to institutionalize the foresight process in such a way that it contributes to national development strategies and addressing local demands. This helps to ensure that the relevant stakeholders are involved not only in building the scenario exercises but also in the related policy initiatives. This highlights the importance of the foresight process in relation to the specific technologies analysed in the foresight exercise. Also, the potential of foresight as a tool at different levels (regional, local, sectoral) emphasizes the importance of capacity-building activities, including through the use of teams of trainers that can facilitate the deployment and transfer of skills.

# VIII. Findings and suggestions

64. The following findings and suggestions were highlighted by the intersessional panel and put forward for consideration by the Commission at its nineteenth session, scheduled to take place in Geneva from 9 to 13 May 2016.

## A. Main findings

65. The emerging digital technologies discussed may create advantages for countries only if they have the required complementary infrastructure (such as, inter alia, human capital, energy infrastructure and legal frameworks) and good quality digital infrastructure (especially broadband connectivity):

(a) Institutionalizing technology foresight as part of existing policymaking and national development planning processes can assist countries to make the best use of the opportunities offered by digital developments and simultaneously address challenges.

(b) Big data analysis and the Internet of things have large potential to contribute to achieving the Sustainable Development Goals but they raise issues of privacy, security and confidentiality of data.

(c) Many big data technologies and artificial intelligence algorithms are built on technology with open access licences. This provides opportunities for inclusive, pro-poor innovation, and for local adaptation of pressing development problems.

(d) Three-dimensional printing has applications in a range of areas relevant for sustainable development, including enterprise development, environmental sustainability, construction and education. However, it could potentially produce negative effects on labour markets, and create security and intellectual property concerns.

(e) Although three-dimension printing has yet to become a widely used manufacturing process, it offers technological opportunities that could reshape production processes. These include potential for mass customization, reduction of variable and fixed costs of manufacturing, and simplification of production chains. Further research is needed to identify the exact scale of potential opportunities and challenges, especially in developing countries and LDCs.

(f) Digital automation can potentially improve workplace productivity and the scale of operations. This could benefit workers by relegating more predictable, routine activities to robots, and create jobs that require new skills. However, automation could potentially reduce the number of jobs available and lead to a change in the composition of employment as well as job functions across sectors. To reduce negative effects on employment, the skills of the labour force should be aligned to the potential employers' new demands.

(g) MOOCs potentially provide an opportunity for countries, especially in resource-poor regions, to provide mass education at low cost. However, MOOCs could potentially widen educational and technological divides if not targeted to those most in need.

## B. Suggestions

66. Member States are encouraged to consider the following courses of action:

(a) Engage in foresight exercises to understand the role of digital developments in their own national contexts, especially in terms of their potential to contribute towards achievement of national and global development goals.

(b) Adopt appropriate national policies to support the development, adaptation and diffusion of emerging digital technologies to take advantage of the technological leapfrogging opportunities created by such technologies.

(c) Develop regulatory policies on data that balance individual and collective rights, and safeguard privacy and security, while ensuring continuous innovation.

(d) Create awareness about the potential threats that digital technologies can pose to citizens' rights and develop appropriate policies and strategies to address them.

(e) Consider harnessing digital developments to the pursuit of sustainable development through government-led efforts (such as, inter alia, public-funded pilot projects) that can inform society on the potential of particular digital technologies.

(f) Continue to promote an enabling environment for digital development through, inter alia, strengthening of the core ICT and complementary infrastructure (such as human capital, energy infrastructure and legal frameworks).

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

(a) Serve as a forum where relevant lessons emerging from such foresight exercises can be shared, including failures and opportunities for growth and development;

(b) Monitor changing digital developments and their implications for sustainable development and particularly for the LDCs.