Expert Group Meeting on Exponential Technological Change, Automation, and Their Policy Implications for Sustainable Development

Mexico City, Mexico, 6 to 8 December 2016

Co-organized by DESA, ECLAC, and the Government of Mexico

Report of the Meeting

Contents

Key Recommendations

1. The following conclusions and recommendations emerged from the discussions:

   a) *Science engagement:* Full engagement of governments, scientists, economists, other experts, the private sector and other stakeholders is needed to address the many areas where further research and assessments are needed, including the impact of emerging technologies to support the full implementation of all the SDGs; the interactions between the existing and the

new technology systems; future pathways and options; as well as potentials and limitations of policies to minimize the negative and maximize the positive impacts of widespread automation. Scientific community is encouraged to work with policymakers to identify and promote best practices. A series of global, sectorial, regional and national studies are needed to identify opportunities and challenges related to accelerated technological change, particularly in the fields of automation, robotics and artificial intelligence. It is necessary to more effectively integrate technological innovation, job creation, capacity building, and maintaining the ecosystem goods and services upon which life depends. We need new ideas for strategies that achieve these objectives, tailored to the situations in individual countries.

b) *Policies at the national level:* There are a number of technology and innovation policy issues at the national level that need particular attention, such as the role of state and the private sector in promoting technology development, innovation, dissemination and adoption; balanced development strategies that take into account employment impacts; equitable educational systems focused on developing complementary skills including vocational training, university-industry linkages**,** and life-long learning; job mobility along with measures to tackle labor market inequalities; local technological capability; entrepreneurship, investment and innovation opportunities; and technology infrastructure that is accessible to all which will have a considerable impact on inequality gaps reduction among and within countries. In this context, all stakeholders need to work together, including governments at various levels, academic institutions, and the private sector.

c) *Technology facilitation:* Systematic technology facilitation is needed at all levels. This requires efficient technology transfer and diffusion to all, including from developed to developing and least developed countries and through South-South and Triangular Exchanges; knowledge sharing on technology development, deployment and diffusion, as well as technology impacts; a national policy space for implementing appropriate industrial, trade and investment policies; improved market access; building of dense networks of intra- and cross-sectoral linkages; public investment in infrastructure, interconnectivity and Internet that is accessible for all; inclusive financial systems, as well as access to financing facilitation mechanisms, with special attention on those form vulnerable and marginalized groups.

d) *Standards:* There is a need for promotion of open standards, certifications, and knowledge sharing by public and private sectors and within countries, in order to offer capacity building on new technologies for all, facilitate broad learning about new technologies, facilitate labour markets in new skills, build entrepreneurship and innovation skills, and promote financing access, particularly for those in vulnerable and marginalized situations. In this context it will also be important to consider making a more efficient patent system ready for accelerated technological change with ever shortening technology life cycles in certain areas.

e) *UN discussion/forum:* There is a need to institute a regular discussion on challenges and opportunities of exponential technological change and automation. The effects of technological change on sustainable development are as challenging and complex as the effects of environmental change. Therefore, solutions-focused discussions of disruptive emerging automation technologies should be a regular item on the agenda of the UN Multi-stakeholder Forum on STI for the SDGs which could bring together studies on rapid technological change and national responses, ensure information exchange and promote the participation of all relevant stakeholders. In this context, it would be useful to explore the

creation of a "group of friends" open to all interested UN Member States. In a coordinated fashion, these discussions could also be brought to the High-level Political Forum, regional sustainable development forums, and other relevant forums in the UN system. Ultimately, it would be useful to institute annual, multi-stakeholder discussions on exponential technological change, possibly to be conducted in a similar way as the Internet Governance Forum.

f) *Contributions by TFM partners:* UN partners in the Inter-Agency Task Team and the Secretary General's 10-Member Group in support of the Technology Facilitation Mechanism (TFM) are encouraged to continue to mobilise, in an effective manner, scientific, technological communities, private sector and civil society to make the emerging body of knowledge accessible to policymakers. More broadly, they could consider strengthening systems of cooperation at the international level to maximize the benefits and avoid the negative impacts of exponential technologies.

g) *Information dissemination and early warning:* The UN are encouraged to support open-access, online repositories of data on emerging automation technologies, universal monitoring and early warning systems, including technology foresight and futures studies, in order to count with better information about what is needed to attend the challenges of the exponential technological change on sustainable development.

h) *Capacity building:* All relevant partners are encouraged to support technical cooperation and know how on technology facilitation of emerging technologies, including automation and artificial intelligence.

i) *Technology assessment:* More in-depth technological studies or assessments are needed on exponential technological change, including automation technologies, and their policy implications for sustainable development, particularly in developing, middle-income countries and least developed countries. All relevant partners under the TFM and beyond are encouraged to cooperate in this regard. Economic and integrated assessment models could be useful tools for quantifying elements of the assessment. Results could be discussed at the STI Forum, the High-level Political Forum on Sustainable Development and other international and regional forums.

j) *Social and political impacts:* Loss of employment has been associated with many factors, including exponential technological change and automation technologies, free trade and migration trends, among others. The relative importance of these factors differs among countries and sectors and over time. Reliable information is needed for all countries, in order to inform evidence-based debates. This is of utmost importance, as misinformation on this topic might – in some cases - lead to social and political unrest.

Introduction

2. The United Nations Department for Economic and Social Affairs (DESA), the Economic Commission for Latin America and the Caribbean (ECLAC), and the Ministry of Foreign Affairs of Mexico organized the *Expert Group Meeting on Exponential Technological Change, Automation, and Their Policy Implications for Sustainable Development* in Mexico City, Mexico, from 6 to 8

December 2016. The meeting was held in Conference Room *Jose Gorostiza* in the premises of the Ministry of Foreign Affairs of Mexico. The programme of the meeting is contained in the Annex.

3. The Expert Group Meeting was attended by 49 experts, senior officials, representatives of civil society and private sector organizations, and United Nations System from ten countries: Austria, Chile, China, Kenya, Mexico, the Netherlands, Spain, Tanzania, the United Kingdom, as well as the United States of America.

4. The three main objectives of the Expert Group Meeting were: (a) to take stock of the knowledge on prospects and challenges of harnessing exponential technological change for sustainable development, with a focus on disruptive automation technologies and key technology areas of development concern, such those related to agriculture and infrastructure including ICTs; (b) identify priority areas of collaborative work and potential mechanisms for international cooperation to help to facilitate the development, transfer and dissemination of these technologies for the achievement of the SDGs, including within the framework of the Technology Facilitation Mechanism; and (c) provide guidance and inputs for the preparation technological assessments on automation technologies and their policy implications for sustainable development, particularly in developing and middle-income countries, which could inform Multi-stakeholder Forum on Science, Technology and Innovation for the Sustainable Development Goals (STI Forum) on the potential effects of those technologies and their impact in achieving the SDGs.

Summary of Discussions

Exponential Technological Change

***Moderator*:**
Mr. Sergio M. Alcocer, President, México Exponencial
***Panelists*:**
Mr. Jose Ramon Lopez-Portillo, Professor, Oxford University
Ms. Faye Duchin, Professor of Economics at Rensselaer Polytechnic Institute
Mr. Xingquan Wang, Associate Professor, Director of Research Center on Knowledge Management and Chief Expert of Think Tank "Creative Economy", Institute of Information Sciences, Shanghai Academy of Social Sciences
Ms. Ann Kingiri, Senior Research Fellow, African Centre for Technology Studies, Kenya
Mr. Rob Atkinson, President, Information Technology and Innovation Foundation (by video)

5. Different views were expressed on what characterizes exponential technology change and on whether today's technology change significantly differs from past patterns:

6. One group of participants provided evidence that today's technological change at least in some areas is happening at a faster pace than in the past - a defining characteristic of exponential technological change. Exponential rates of change can be observed through fast improvements in performance, capabilities, efficiency and synergies with other technologies, which in turn resulted in exponential accumulation of information and knowledge. Progress of many technologies follows exponential paths at various rates. Synergies between these technologies arising from common components and other factors lead to exponential change also at aggregate levels. In this context,

general purpose technologies, including information and communications technologies (ICTs) and the Internet in particular.

7. Another group of participants provided evidence for similar rates of technology change today as in the past. This group also noted that technological change is exponential in nature and follows a common pattern of adoption and diffusion that can be characterized by S-shaped curves. However, at any point in time different technologies are in different stages of the S-shaped curve, which affects the perceived overall pace of change. Some experts noted that many emerging technologies are currently at the steeper part of the curve (meaning faster pace of change than in the past), while others emphasized that many technologies are currently close to the top of the curve (meaning a slower pace of change than in the past). It was also noted that innovation depends on the creation of new firms and sectors – a process which limits the pace of technology change.

8. A third group of participants stated that they did not consider the pace of change as less interesting than the impact or qualitative change caused by current technological progress. They argued that a key issue is the labour-saving bias of technological change, typically leading to lower demand for low skilled labour - with tremendous social implications.

9. In terms of scope, most participants were of the view that today's exponential technological change is different from past patterns of change due to many factors, including: technology change is faster than our ability to adapt to them; some technologies such as artificial intelligence (AI) could compete with humans in terms of cognitive tasks; a large part of the workforce in developed countries is affected at once given the widespread adoption of information and communication technologies (ICTs); technological change affects white-collar and professional jobs, as well as blue-collar jobs; there is a cross-over between ICTs and physical and biological technologies, which increases the scope of change; there are network effects and increasing interconnections between economies through global value chains; enhanced networking and collaboration in the process of technological change tend to encourage open-source, which facilitates diffusion; and exponential technological change affects the whole industry chain in many productive sectors. Technological frontiers now span from the smallest to the largest scale: nanomaterials bridge bulk materials with atomic or molecular structures; there is gene-level manipulation of plants and animals, including the human genome; while privatization of space travel technology increases the prospects for mining and colonization of the space.

10. Views also differed on the expected impacts of exponential technological change:

11. Some participants expressed their great expectations for transformational change resulting from current technological change, leading to sustainable and inclusive improvements of people's lives within "planetary boundaries". In their view, automation will amplify people's ability to manipulate new knowledge leading to innovation. Some participants called for local demonstration projects pioneering new and emerging technologies to achieve the sustainable development goals.

12. Other participants emphasized the negative impacts of automation on employment. In their view, the dissatisfaction of large parts of the middle class in many developed countries is at least partially due to jobs being made redundant by automation. While at present direct impacts are primarily felt in developed countries, similar issues will soon arise in developing countries, especially as they are ill adapted to absorb the new technologies in a meaningful way. Furthermore, different segments of society have different capacities to benefit from technological change, which affects

societal power dynamics. As a result, inequality between and within countries will most likely increase further.

13. Technological changes go along with changes in production supply, demand, and governance. In this regard, exponential technologies typically create new industrial opportunities, but also lead to social and institutional changes. Therefore, diffusion, appropriation and financing of technologies, as well as inclusion at national and international levels are important concerns. Information technologies enable and amplify all other technologies. Hence, it is important to improve overall literacy which includes computer and mathematical literacy.

14. Some experts noted that the challenge is too few technology diffusion too slowly.

15. Regardless of their views on specific issues, participants agreed on the relevance of the issues discussed and on the need for further exploring the effects of technological change on sustainable development. Experts from public and private sectors around the world expect broad and far-reaching change in the coming years. In particular, private sector people highlight the important trend toward convergence among scientific, technological, industrial applications and services applications. Participants called for systematic research on this topic, in order provide reliable evidence to support decision-making. In this context, the United Nations was encouraged to organize an in-depth assessment on how technological change can affect the achievement of the SDGs.

Emerging Technologies and their Applications

***Moderator*:**
Ms. Norma Munguía, Director General for Global Issues, Ministry of Foreign Affairs of Mexico
***Panelists*:**
Ms. Laura Palomares, Professor, Institute of Biotechnology, UNAM
Mr. Andrew Maynard, Professor, School for the Future of Innovation in Society in Arizona State University
Mr. Edgar Barroso, Professor, Instituto Tecnológico de Estudios Superiores de Monterrey, Campus Santa Fe, Mexico

16. A range of key (existing and emerging) technologies were discussed, including in the following areas: artificial intelligence (and the trend towards creating artificial general intelligence), information technology and computing, big data analytics, artificial-intelligence-endowed robotics, unmanned vehicles, Internet of Things, nanotechnology, materials science, 3D-printing, biotechnology, synthetic biology, genetic sequencing, genome modification, medicine and neuroscience, and virtual and augmented reality. It should be noted that the disruptive potential of these technologies is multiplied when they are combined in innovative ways. Among them, artificial intelligence and robotics are examples of automation technologies, while the others are enabled by automation.

17. There are multiple benefits of these emerging technologies for consumers, including in the form of new goods and services that are cheaper and of better quality, resulting in increased consumer welfare.

18. Some participants emphasized that we live in a world with tremendous needs and there is an large gap between what can be done and what is actually done with these technologies. In that regard, trends were identified in relation to what is done with materials, mechanics, and digital systems. In

the technologies related to materials, working is underway to manipulate the building blocks of everything. In mechanics, progress continues in the way that manufacture is carried out, such as the introduction of sophisticated processes to produce products on demand. In relation to digital systems, there is a sense that computers are getting better than humans in doing work. It was noted that the major excitement is at the convergence of these three trends. The capabilities that could emerge at the intersection of these three trends could be transformative.

19. In particular, the meeting noted the evolution of biotech in the past 30 years and how computers have played a big role in biology in dealing with the vast amounts of data, for example in relation to the human genome. Changes in technology have generated changes in paradigm in how health treatments are delivered, which now includes a more active role of the patients. It was noted that in some cases AI could make better decisions than physicians, which poses challenges and opportunities. A challenge highlighted was that people is now consuming more drugs which could increases the risk of antibiotic and antiviral resistance. In that connection, education is key to address misinformation. Another challenge noted is that technology is not attending diseases relevant in underdeveloped areas. Changes of way of life have also resulted in new ailments such obesity, hearing and eyesight loss, muscle and articular pain, depression and other mental health problems.

20. The meeting also noted the great changes are happening in production due to adoption of emerging automation technologies. In that connection, it was recognized that only countries that have capability in production will benefit from that revolution. As result, in the future it is expected that there will be more variety of production technologies, and there is the risk that poorer countries will lag further behind in terms of technological gap. The meeting also noted that the application of production technologies is constrained by the availability of factors of production, including natural resources. Therefore, there is the need to take into consideration resource use when considering the benefits and applications of emerging production technologies.

21. Some experts were of the view that manufacturing is less important today and will be even less important in the future. They argued that the focus should be on the application of the technologies to a services-based economy, and the important is our capacity of manipulate information and new knowledge. Others were of the view that increases in the service sector are related to increases in industry- and manufacturing-related services; therefore, manufacturing would continue to have an important role in the economy, and the effects of automation would continue to be a relevant discussion.

22. The meeting emphasized the importance of education in facilitating the dissemination, adoption and application of emerging technologies. In that regard, it was noted the need to transform traditional educational systems into life learning systems, in which, in addition to basic education, people learn how to learn and creativity is considered a key element. It were also emphasized the need to bring different of knowledge fields together in the leaning process, to include technical and vocational training, to expand career options and to recognize the key role of ‘learn by doing’.

Exponential Technological change and Automation: Potential Impacts on Development and Sustainability in Key Areas of Concern

Moderator:
Mr. Richard Alexander Roehrl, Senior Economic Affairs Officer, UN Department for Economic and Social Affairs (DESA), New York

Panelists:
Ms. Bitrina Diyamett, Executive Director, Science, Technology and Innovation Policy Research Organization, Tanzania
Ms. Faye Duchin, Professor of Economics at Rensselaer Polytechnic Institute, USA
Mr. Zhang Chenggang, Professor and Vice dean, School of Social Sciences, Director, Research Center for Social Innovation and Risk Management, Tsinghua university, Beijing

23. The meeting discussed the potential impact of technological change and automation in the achievement of the sustainable development goals (SDGs). Many experts argued that they pose threats, mostly related to jobs loss and inequality. Some other experts were of the view that the impact would be mostly negative for developing countries and they pointed to the following mechanism: capabilities required to develop, adapt and use these technologies are concentrated in developed countries, which would reduce cost of production in these countries and, through trade, would make less developed countries become even less competitive in many sectors. In many cases, production could move back to developed countries. The increasing technological gap would further hinder the prospects of poorer countries to industrialize and catch up.

24. Other experts were of the view that there is a threat for both developed and developing countries. It was argued that even the classification of developed and developing countries as monolithic groups are not appropriated in this context. For example, developing nations could be divided in more than one group, namely those that are able to catch up and those that are not catching up, and the effects of technological exponential changes in these countries would be very different. The meeting emphasized that different mechanisms are at play but the final result is that the effects of exponential technological change and automation are a global issue.

25. Other experts argued that the potential of exponential technological change could be positive or negative depending on the policies in place to steer the process of innovation towards a socially desirable direction. It was noted that effects would also depend on the specific technologies and initial conditions of each country. In that regard, it was emphasized the need to build scenarios and use models to better understand the potential effects of technological change on sustainable development.

26. In the African context, it was noted that production and industrialization are major issues for countries of that region. It was emphasized the key role of employment in reducing poverty and how manufacturing is considered as a key sector for the creation of jobs. However, it was noted that countries in Africa cannot compete even in low-tech industries, and the majority of the population is employed in subsistence agriculture and low-wage work in the services sector that do not provide decent jobs. As result, Africa is exporting labour force to other countries and the continent is experiencing a trend of deindustrialization.

Scenarios for the Development, Dissemination and Adoption of Automation Technologies

Moderator:
Mr. Richard Alexander Roehrl, Senior Economic Affairs Officer, UN Department for Economic and Social Affairs (DESA), New York
Panelists:
Mr. Jose Ramon Lopez-Portillo, Professor, Oxford University
Ms. Faye Duchin, Professor of Economics at Rensselaer Polytechnic Institute, USA

Mr. Edmundo Molina, Professor, Instituto Tecnológico de Estudios Superiores de Monterrey, Campus Santa Fe, Mexico
Mr. Xingquan Wang, Associate Professor, Director of Research Center on Knowledge Management and Chief Expert of Think Tank "Creative Economy", Institute of Information Sciences, Shanghai Academy of Social Sciences

27. The meeting noted that different pathways of technology change makes difficult to predict plausible scenarios for the development, dissemination and adoption of automation technologies in the production base of developed and developing countries. Technological systems are inherently complex systems: non-linear, not predictable, and vulnerable to catastrophic failure. Even well-intentioned interventions change the nature of the system itself.

28. In that connection, the meeting noted seven key uncertainties related to technological progress: the structure of international supply chains; the pace of technological change; how quickly technologies can be commercialized; how labor markets will develop; the trajectory of innovation system in developing countries; the development of critical infrastructure in developing countries; the evolution of internal markets in developing countries; and the evolution of venture capital across borders. However, although it is not possible to predict the future of technological change, some experts were of the view that it is possible to anticipate near future changes.

29. In an optimistic scenario, at national level, technology change would increase productivity and that would be shared equally over the working population. In a pessimistic scenario, the gains in productivity would be captured by a small elite.

30. The meeting noted that recent economic history shows that we should care about which countries can adopt those technologies. It was also noted that the absorption and learning capacity of firms in developing countries depend on the technology gap between them and firms at the technological frontier in developed countries. Higher capacity in developed countries may result that use of automation technologies could be limited to these countries, while developing countries would have limited time to learn, which would make catch up more difficult. In that regard, the meeting noted the need for the development of scenarios and models that take into consideration the innovation capacity and technological gap among countries. It was also highlighted the importance of sectoral analysis and the need to consider different levels of aggregation.

31. Some experts noted that, whenever countries were able to catch up, Governments played a leading role in fostering the investment required to close the technological gap through the combination of public policy and private enterprise. In that regard, experts argued for structural policies to promote development. Larger emerging economies may be able to pursuit such strategy by their own but others will need international cooperation. The meeting also noted the need to pay attention to macroeconomic issues that affect how technology is disseminated, which depend on finance and investment. In that regard, the meeting noted the need to develop models and scenarios to analyze the effects of those policies and strategies, and recognized the potential role and real possibility for cooperation at the international level in carrying out that work.

Impact of Automation Technologies on Employment

Innovation and Technological Unemployment

Moderator:

Mr. Clovis Freire, Economic Affairs Officer, DSD, DESA
Panelists:
Mr. Jose Ramon Lopez-Portillo, Professor, Oxford University
Mr. James Bessen, Lecturer in Law at the Boston University School of Law (by video)
Ms. Gabriela Dutrénit Bielous, Professor, Universidad Autonoma Metropolitana, Mexico
Mr. Bart Verspagen, Director-Dean of the Maastricht Graduate School of Governance (MGSoG) at Maastricht University and Director of United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT)

Potential Effect on Employment in Developed and Developing Countries

Moderator:
Mr. Wilson Perés, Senior Economic Affairs Officer, Division of Production, Productivity and Management at ECLAC
Panelists:
Ms. Ann Kingiri, Senior Research Fellow, African Centre for Technology Studies (ACTS), Kenya
Mr. Zhang Chenggang, Professor&Vice dean, School of Social Sciences, Director, Research Center for Social Innovation and Risk Management, Tsinghua University
Ms. Bitrina Diyamett, Executive Director, Science, Technology and Innovation Policy Research Organization, Tanzania
Mr. Ludovico Alcorta, Director, Research and Statistics Branch of the United Nations Industrial Development Programme (UNIDO)
Mr. Edmundo Molina, Professor, Instituto Tecnológico de Estudios Superiores de Monterrey, Campus Santa Fe, Mexico

32. The meeting discussed the effect of innovation on employment, including the mechanisms through which technological change affects employment, the extent that innovation has caused technological unemployment, and the potential impact in countries at different stages of development.

33. The meeting noted that there is broad agreement among experts that innovation may result in temporary job losses. However, a point of disagreement is whether innovation has long lasting negative effect on aggregate employment.

34. The mainstream view in Economics is that short term technological unemployment is counterbalanced by compensation effects. These effects include lower prices of products due to process innovation, which increase real income and result in increasing demand for goods and services, and consequently increase the demand for workers. Another effect is the savings in production costs, which increase revenues and the potential for investment, and may also increase the number of jobs. Innovation also creates new goods and services; therefore, it may destroy jobs in some sectors but creates new jobs in new sectors.

35. The meeting also noted the different effects of product and process innovation on employment. In general, process innovation reduces employment, while product innovation raises demand and stimulates employment. However, it is hard to quantify magnitudes and relative changes. Most estimates consider the effect of innovation on developed economies and more effort should be made to consider the possible effects in developing and less developed countries as result of technological change as well as of international trade, export and integration into the global values chains. The meeting also noted that a challenge in places with high unemployment and

underemployment is not so much to move from one job to another but to move into employment. Hence the complexity of measuring this link in developing countries where there is a high level of informality.

36. Regarding the impact on employment of emerging automation technologies, in particular technologies such as artificial intelligence and data analytics, the meeting noted the opposing optimistic and pessimistic views. Experts that subscribe to the former are of the view that the compensation effects of technological change will continue to work as they have worked in the past. They argued that there is no limited amount of jobs to be replaced by automation given that new jobs are created to meet what seems to be unbounded "human wants". Whenever new jobs are created by technological change the result are more and better jobs that provide higher paying and require more skills. These experts argued that countries at the technological frontier will most likely gain in terms of productivity and they will face reduced impact on employment. On the other hand, developing countries will be affected negatively because technology catch up becomes more difficult. Other experts noted that the effect of automation on employment may be stronger and arise faster in countries with stronger manufacturing sector, including large emerging economies. The net effect of automation on employment depends on circumstances and on policies to reduce the negative impacts.

37. An important difference noted is between the complete replacement of a job or occupation and the replacement of parts of jobs. Some experts noted that automation involves the use of machines to replace tasks within an occupation. They argued that very rarely technology automation completely replaces jobs; it has usually a partial effect and replaces only parts of jobs. As an example, it was noted that, in the United States, occupations that are computerized employ more people, while other less computerized jobs have disappeared. From a distributional point of view, there is change in employment but the aggregated number of jobs may not change. That may also result in changes in the organization of work, including on where the work is conducted, but that reorganization may not reduce the aggregate number of jobs. In a near future, automation will continue to provide tools that enhance the productivity of workers without replacing jobs. It is possible that few occupations would be completely replaced in the next 10 or 20 years. However, job areas that are being computerized are areas with higher demand elasticity. Nevertheless, we may see a greater increase of inequalities across and within countries.

38. Experts that subscribe to the pessimistic view of the effect of automation on employment argue that the compensation effects of innovation, although effective in the past, may be less effective in the future. An extreme view is that, in the long run, computers and robots would be able to perform all work and there might not remain enough jobs for humans. Some estimates suggest that in developed countries almost half of jobs will be replaced by computerization and robotization in the coming decades.

39. The meeting also noted the importance to discuss incomes and not only distribution and levels of employment. Technological change has historically shown some biases in that regard; it has saved more labour of one kind ("low-skill") than of other kinds. If the ratio of capital to labour increases then the ratio of labour income to capital income tends to fall because by-and-large capital and labour substitute easily. In manufacturing, this effect tends to be weakest for medium-skilled labour because manufacturing tend to be medium-skill intensive. Therefore, manufacturing has traditionally been the relative safe harbour for the mass population of workers. Historically, technological change mainly replaces low-skilled labour. In an ideal world, replaced workers will acquire medium-level skills and become employed in manufacturing and some modern services sectors, where they earn a decent living that enables them to exercise demand that offsets the negative effects of process innovation.

However, that is a delicate equilibrium. Automation, robotization and AI may imply that especially the degree of substitutability of capital and medium-skilled labour will increase drastically, which will make income from medium-skilled labour much more responsive to investments in capital goods (i.e. machines). Hence the safe harbour will disappear, leading to unemployment, increased polarization of income distribution, and hinder mobility of middle income groups.

40. The meeting noted that recommendations to developing countries on how to reduce the negative effects of innovation on jobs should not be based only on the evidence coming from developed economies. Given that the compilation of evidence from developing economies will take time, a possible solution is to build scenarios on the impact of adoption of modern automation technologies in developing countries based on their initial conditions, including economic structure, specialization, level of education of the workforce, institutional and regulatory frameworks, and international and local industries dynamics. In that connection, there is the need of a set of scenarios for different type of initial conditions, identifying emerging niches and job skills required for their development. Based on these scenarios, it may be possible to define potential development strategies, to identify policy areas that must be coordinated, as well as policy options.

41. Other aspect that would merit further discussions is the collection and analysis of evidence on the link between innovation and employment in developing countries, specifically on the direct and indirect effects and how they differ. It is also important to consider the type of innovations that will be potentially introduced in developing countries and in specific industries. These countries will be in general adopters of automation technologies, so they will introduce process innovation, which generate productivity gains but is labour-displacing. On the other hand, these countries produce less product innovation; therefore the direct and positive effect of product innovation on employment will be missing.

42. Another dimension that was emphasized is the potential impact of innovation on the availability of resources. Product innovation may create new demand and jobs but it may increase resource use and environmental pressure that could lead to an unsustainable development path. In that regard, all countries should seek to pursuit sustainable production and consumption. New waves of sustainable product innovation could put the economy in a new path of employment that is also environmentally sustainable. In that regard, development strategies need to meet needs anticipated for the future, such as those identified in the SDGs involving for example new forms of energy and technologies for better management of water resources. Developing countries have advantages for becoming major actors in renewable energy (from widely distributed solar radiation to rich lithium deposits in South America), and dealing with their own very serious water problems can be the impetus for developing goods and services for export.

Impact on Structural Transformation, Sustainable Industrialization and Catch up

Moderator:
Mr. Arturo Borja, Deputy Director General, CONACYT
Panelists:
Mr. Ludovico Alcorta, Director, Research and Statistics Branch of the United Nations Industrial Development Programme (UNIDO)
Ms. Gabriela Dutrénit Bielous, Professor, Universidad Autonoma Metropolitana, Mexico

Mr. Bart Verspagen, Director-Dean of the Maastricht Graduate School of Governance (MGSoG) at Maastricht University and Director of United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT)

43. The meeting discussed the potential effects of emerging automation technologies on industrialization and structural transformation in developing and least developed countries, taking into account historical experiences. Some experts were of the view that the effects would be mostly negative for developing and least developed countries. Educational level of workforce in developing countries leaves them ill equipped to absorb technological innovations. Future success depends on degree of economic openness, quality and level of education and the dissemination of opportunities for all.

44. Other experts noted that it is difficult to fully anticipate the effects and that the formulation of specific desirable scenarios could help to analyze ways to reach them. For example, it is possible that automation would restore some competitive advantage of high cost nations in terms of tradable goods, while the opposite may happen in terms of services, with more work able to be done at distance.

45. The meeting noted that much of the impact of technological change on low and middle (and high) income countries' structural transformation will depend on the industries they are involved in and their level of income. Technological change is not expected to be disruptive in low tech industries, such as garments or textiles; therefore, no significant impact on value added, employment and productivity should be expected in less developed countries that rely on that industry. Insofar as medium tech industries such as fabricated metals face transformative technological change, middle income countries engaged in such industries may face growing labour productivity but at the expense of even slower employment growth. However, there may be some employment compensation due to product diversification. In industries like non-metallic minerals and basic metals, whose value added, employment and productivity growth remains relatively stable at all levels of income, very little impact is expected in middle and high income countries unless technological change is massively disruptive. Insofar as technological change will be highly disruptive in high tech industries, middle and high income countries involved in industries such as machinery and equipment and electrical machinery and apparatus will face even faster growing labour productivity at the expense of employment, although product diversification effects on employment may also be observed. In industries such as motor vehicles, where a relative 'commodification' of output is taking place, middle and high income countries involved in these industries may also face increases in labour productivity not only as a result of falling employment but also value added. Overall, since disruptive technological change is affecting high tech industries more than low tech industries, the effects on value added, employment and productivity should be more pronounced in middle and high income countries engaged in these industries, hence limiting the potential for least develop and some middle income countries to structurally transform their economies, unless policies to address these negative effects are set in place.

46. Experts emphasized the paradigm shift that characterizes diffusion and deployment of technological revolutions. In that regard, they were of the view that we are at the installation stage of a new paradigm, still far from the deployment, but there is no certainty on what this paradigm is about and hence what are the radical innovations that will emerge. New automation technologies are based and combine technologies of the previous paradigm (e.g. mass production, ICT and electronics). These technologies are largely associated with negative effects on environment, which require compensatory actions. The meeting noted that the impact of that technological revolution will depend on initial conditions, including the economic structure, specialization, level of education and skills of

the workforce, institutional and regulatory framework, and how far countries are from the technological frontier. The ability of countries to benefit from the new technological paradigm depends on national development strategies, including the formulation of STI and other interconnected policies (e.g. industrial, economic, social, and environmental), as well as the timing of their implementation. A challenge is how to move along a development trajectory based on these technologies while reducing inequality and ensuring a sustainable future. Totally new technological areas may emerge as the new areas for opportunities. That would require the identification and fostering complementarities between systems of production, innovation, education and institutional development. Education was highlighted as a key area of policy change.

47. The meeting also noted that much of the discussion on the impact of automation on structural transformation in developing and least developed countries is focused on industrialization without considering sustainability. In that regard, more effort should be made to put sustainability at the centre of the analysis and policy debate in the area of automation, considering both sustainable forms of production and consumption.

48. Experts have noted that leapfrogging towards sustainable technologies is difficult. Innovation is a learning process and depends on the existing production knowledge in the economy. Product innovation in developing countries is usually the result of imitation of production that already exists in more advanced economies. In that regard, developed and developing countries that are near to the technological frontier are in a better position to lead the development of more sustainable technologies. Sustainable automation innovations, as well as other emerging technological paradigms, could become stepping stones for developing countries with an established manufacturing base to reduce the income gap in relation to developed economies. Less technologically advanced countries would eventually adopt those technologies as part of the product imitation process.

Impact of Automation Technologies on Inequality

***Moderator*:**
Ms. Julia Tagüeña, Deputy Director General, CONACYT
***Panelists*:**
Mr. Michael Zichy, Assistant Professor, Department of Philosophy at the Faculty of Catholic Theology, University of Salzburg
Mr. James Bessen, Lecturer in Law at the Boston University School of Law (by video)
Mr. Rob Atkinson, President, Information Technology and Innovation Foundation (by video)
Ms. Ann Kingiri, Senior Research Fellow, African Centre for Technology Studies, Kenya
Mr. Zhang Chenggang, Professor and Vice dean, School of Social Sciences, Director, Research Center for Social Innovation and Risk Management, Tsinghua university, Beijing

49. The meeting discussed the potential effects of automation technologies on various segments of population in developed and developing countries, and the impact on inequality within and across countries. The discussion focused on the impact on income inequality but the meeting emphasized that concerns about inequality apply to all SDGs.

50. Some experts were of the view that artificial intelligence will exacerbate forces towards inequality within countries. People that are less educated, least skilled and those leaving outside the economic centers will be more negatively affected. Job losses as result of automation tend to disproportionally affect low wage jobs and low-wage workers lack the skills to transition to high wage

occupations, therefore inequality increases. There is also a tendency of computer automation to exacerbate inequality within occupations. In that regard, better education and skills development of the workforce is important but more important is the access to the work opportunities. Workers who use information technology learn new skills on the job and earn higher wages, but the opportunity to work is distributed unequally, favoring more educated and higher paid workers, which increase wage inequality both within and across occupations. Where skills cannot be taught widely or learned on the job, inequalities will emerge. Discussing in the context of developed economies, some experts were of the view that what is driving inequality is a matter of access to those computer-assisted work opportunities, which will also drive higher inequality between developed and developing countries. The challenge for education policy is that skills are mainly acquired in the job rather than in the class room and technology change very rapidly. In that regard vocational education and certification of skills are important policy areas. Another challenge is that sometimes skills can be developed only in companies that have access to specific data that is proprietary even when the code/algorithm is open source. Experts emphasized that without sufficient policy attention to those issues, inequality will rise.

51. In relation to the impact of emerging automation technologies on inequality across countries, experts were of the view that these technologies will remain being developed and employed in technologically more advanced developed and developing countries, big companies, and in related and supply industries. For most of the developing countries the production process will remain a black box. In that regard, there is a need to better understand the role of the private sector and multinationals in particular in the dissemination and adoption of those innovations in technologically less advanced countries. There was the recognition that automation would play a different role for different countries. There is not a uniform style of modernization in the world, and therefore there should be a multi-modality strategy for different countries, different cultures, societies, and capabilities.

52. Some other experts were of the view that emerging automation technologies have no effect in inequality. They argued that most of the observed growing inequalities in developed countries are found within occupations and not across occupations. They view that the challenge for most developing nations is low productivity, which in turns translates into low wages, and argue that is a mistake to slow down needed productivity gains for concerns about inequality that could very well not emerge. The meeting also noted the view that a key challenge for reducing inequality in the future is the new economic normal of low growth. Fast global growth in the past decade, particularly in developing and emerging economies, have reduced poverty around the world and reduced inequality in some regions such as the Latin American and Caribbean region.

53. Experts also noted that technologies embed values and some of them may increase disparities such as gender inequality. The challenge is how to develop policies that foster the development of technologies that embed equalitarian values. The meeting also noted other ethical aspects of automation. The discussion was guided by a framework for ethical appraisal of innovations based on three fundamental moral values: freedom and autonomy; wellbeing and quality of life; and justice and equality. Experts noted the resulting recommendations to support and protect developing countries; invest in education; support SMEs, adapt taxation systems for redistributions; and developed strategies for unskilled left-behind, which could include the provision of basic living means, and provision of meaningful job activities. Many other values could be included in the analysis. A more comprehensive evaluation would include environmental and cultural values, for example. It was noted the need to pursuit similar exercises also including mechanism to identify the values that are relevant for different communities and groups of the society. There was also a call to move the discussion to the grassroots level and identify what are the positive attributes of these innovations that can immediately benefit the poor.

Programme

Tuesday, 6 December 2016

10:00 – 10:30 Opening

Welcome remarks:

- Mr. Richard Alexander Roehrl, Senior Economic Affairs Officer, UN Department for Economic and Social Affairs, New York
- Mr. Hugo Eduardo Beteta, Director, ECLAC Sub regional headquarters in Mexico

Opening remarks:

- H.E. Mr. Miguel Ruíz Cabañas, Undersecretary for Multilateral Affairs and Human Rights, Ministry of Foreign Affairs, Mexico

10:30 – 10:45 *Coffee break*

10:45 – 11:00 *Setting the stage: Objectives of the meeting and context - UN Technology Facilitation Mechanism, STI Forum, and UN Regional Fora on Sustainable Development*

Presentation:

- Mr. Clovis Freire, Economic Affairs Officer, UN Department for Economic and Social Affairs, New York

Q&A

11:00 – 12:30 Session 1: *Exponential technological change*

Key questions: *What characterizes exponential technology change and does it differ from past patterns of technology change? If so how does it differ (e.g., in terms of pace, scope and potential impact)?*

Moderator:

- Mr. Sergio M. Alcocer, President, México Exponencial

Panellists:

- Mr. Jose Ramon Lopez-Portillo, Professor, Oxford University
- Ms. Faye Duchin, Professor of Economics at Rensselaer Polytechnic Institute, USA
- Mr. Xingquan Wang, Associate Professor, Director of Research Center on Knowledge Management and Chief Expert of Think Tank "Creative Economy", Institute of Information Sciences, Shanghai Academy of Social Sciences
- Ms. Ann Kingiri, Senior Research Fellow, African Centre for Technology Studies, Kenya
- Mr. Rob Atkinson, President, Information Technology and Innovation Foundation **(by video)**

Q&A and plenary discussion

12:30 – 14:30 *Lunch break*

14:30 – 16:00 Session 2: *Emerging technologies and their applications*

Key question: *What are the key existing and emerging automation technologies? Where are they currently being used?*

Moderator:

- Ms. Norma Munguía, Director General for Global Issues, Ministry of Foreign Affairs of Mexico

Panellists:

- Ms. Laura Palomares, Professor, Institute of Biotechnology, UNAM
- Mr. Andrew Maynard, Professor, School for the Future of Innovation in Society in Arizona State University
- Mr. Edgar Barroso, Professor, Instituto Tecnológico de Estudios Superiores de Monterrey, Campus Santa Fe, Mexico

Q&A and plenary discussion

16:00 – 16:15 *Coffee break*

16:15 – 17:45 Session 3: *Exponential technology change and automation - potential impacts on development and sustainability in key areas of concern (e.g., sustainable consumption and production, poverty, agriculture, infrastructure, ICTs)*

Key question: *What are the potential impacts of automation technologies on development and sustainability in general and on the achievement of the SDGs in particular?*

Moderator:

- Mr. Richard Alexander Roehrl, Senior Economic Affairs Officer, UN Department for Economic and Social Affairs (DESA), New York

Panellists:

- Ms. Bitrina Diyamett, Executive Director, Science, Technology and Innovation Policy Research Organization, Tanzania
- Ms. Faye Duchin, Professor of Economics at Rensselaer Polytechnic Institute, USA
- Mr. Zhang Chenggang, Professor & Vice dean, School of Social Sciences, Director, Research Center for Social Innovation and Risk Management, Tsinghua university, Beijing

Q&A and plenary discussion

Wednesday, 7 December 2016

9:00 – 10:30 Session 4: *Possible scenarios of development, dissemination and adoption of automation technologies*

Key questions: *Based on the historical evidence, what are plausible scenarios related to the development, dissemination and adoption of automation technologies in the production base of developed and developing countries? What do these scenarios mean for sustainable development sustainable development aspirations?*

Moderator:

- Mr. Richard Alexander Roehrl, Senior Economic Affairs Officer, UN Department for Economic and Social Affairs (DESA), New York

Panellists:

- Mr. Jose Ramon Lopez-Portillo, Professor, Oxford University
- Ms. Faye Duchin, Professor of Economics at Rensselaer Polytechnic Institute, USA
- Mr. Edmundo Molina, Professor, Instituto Tecnológico de Estudios Superiores de Monterrey, Campus Santa Fe, Mexico
- Mr. Xingquan Wang, Associate Professor, Director of Research Center on Knowledge Management and Chief Expert of Think Tank "Creative Economy", Institute of Information Sciences, Shanghai Academy of Social Sciences

Q&A and plenary discussion

10:30 – 11:00 ***Coffee break***

11:00 – 12:30 Session 5: ***Innovation and technological unemployment***

Key questions: *What are the mechanisms through which technological change impacts employment? To which extent has innovation caused technological unemployment? Will the future be different because of emerging automation technologies?*

Moderator:

- Mr. Clovis Freire, Economic Affairs Officer, DSD, DESA

Panellists:

- Mr. Jose Ramon Lopez-Portillo, Professor, Oxford University
- Mr. James Bessen, Lecturer in Law at the Boston University School of Law **(by video)**
- Ms. Gabriela Dutrénit Bielous, Professor, Universidad Autonoma Metropolitana, Mexico
- Mr. Bart Verspagen, Director-Dean of the Maastricht Graduate School of Governance (MGSoG) at Maastricht University and Director of United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT)

Q&A and plenary discussion

12:30 – 14:30 ***Lunch break***

14:30 – 16:00 Session 6: ***Potential effect on employment in developed and developing countries***

Key questions: *How will emerging automation technologies impact employment in countries at different stages of development?*

Moderator:

- Mr. Wilson Perés, Senior Economic Affairs Officer, Division of Production, Productivity and Management at ECLAC

Panellists:

- Ms. Ann Kingiri, Senior Research Fellow, African Centre for Technology Studies (ACTS), Kenya
- Mr. Zhang Chenggang, Professor&Vice dean, School of Social Sciences, Director, Research Center for Social Innovation and Risk Management, Tsinghua University
- Ms. Bitrina Diyamett, Executive Director, Science, Technology and Innovation Policy Research Organization, Tanzania
- Mr. Ludovico Alcorta, Director, Research and Statistics Branch of the United Nations Industrial Development Programme (UNIDO)
- Mr. Edmundo Molina, Professor, Instituto Tecnológico de Estudios Superiores de Monterrey, Campus Santa Fe, Mexico

Q&A and plenary discussion

16:00 – 16:15 *Coffee break*

16:15 – 17:45 Session 6 continued….

Thursday, 8 December 2016

9:00 – 10:30 Session 7: *Implications for structural transformation, sustainable industrialization and catch up*

Key questions: *What are your views on the potential effects of emerging automation technologies on industrialization and structural transformation in developing and least developed countries, taking into account historical experiences?*

Moderator:

- Mr. Arturo Borja, Deputy Director General, CONACYT

Panellists:

- Mr. Ludovico Alcorta, Director, Research and Statistics Branch of the United Nations Industrial Development Programme (UNIDO)
- Ms. Gabriela Dutrénit Bielous, Professor, Universidad Autonoma Metropolitana, Mexico
- Mr. Bart Verspagen, Director-Dean of the Maastricht Graduate School of Governance (MGSoG) at Maastricht University and Director of United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT)

Q&A and plenary discussion

10:30 – 11:00 *Coffee break*

11:00 – 12:30 Session 8: *Implications for reducing inequality*

Key questions: *What are your views on potential effects of automation technologies on various segments of population in developed and developing countries? What does this mean in terms of inequality within and across countries?*

Moderator:

- Ms. Julia Tagüeña, Deputy Director General, CONACYT

Panellists:

- Mr. Michael Zichy, Assistant Professor, Department of Philosophy at the Faculty of Catholic Theology, University of Salzburg
- Mr. James Bessen, Lecturer in Law at the Boston University School of Law **(by video)**
- Mr. Rob Atkinson, President, Information Technology and Innovation Foundation **(by video)**
- Ms. Ann Kingiri, Senior Research Fellow, African Centre for Technology Studies (ACTS), Kenya
- Mr. Zhang Chenggang, Professor&Vice dean, School of Social Sciences, Director, Research Center for Social Innovation and Risk Management, Tsinghua University

Q&A and plenary discussion

12:30 – 14:30 *Lunch break*

14:30 – 16:00 Session 9: *Key policy recommendations relevant to the STI Forum*

Key questions: *What are the key policy actions (if any) to address the challenges and harness the opportunities you have identified? In particular, which of these policy actions should be considered by the UN Multi-stakeholder Forum on Science, Technology and Innovation for the SDGs and/or the Forum of the Countries of Latin America and the Caribbean on Sustainable Development?*

Moderator:

- H.E. Mr. Miguel Ruíz Cabañas, Undersecretary for Multilateral Affairs and Human Rights, Ministry of Foreign Affairs, Mexico

Panellists:

- Mr. Lenni Montiel, Assistant Secretary-General for Economic Development, DESA
- Ms. Bitrina Diyamett, Executive Director, Science, Technology and Innovation Policy Research Organization, Tanzania
- Mr. Xingquan Wang, Associate Professor, Director of Research Center on Knowledge Management and Chief Expert of Think Tank "Creative Economy", Institute of Information Sciences, Shanghai Academy of Social Sciences
- Mr. Victor Carreón, Deputy Director General, CONACYT
- Mr. Wilson Perés, Senior Economic Affairs Officer, Division of Production, Productivity and Management, ECLAC

Plenary discussion

16:10 – 16:30 *Closing session*

- Mr. Lenni Montiel, Assistant Secretary-General for Economic Development, DESA
- H.E. Mr. Miguel Ruíz Cabañas, Undersecretary for Multilateral Affairs and Human Rights, Ministry of Foreign Affairs, Mexico

16:00 – 16:10 Group photo

List of Participants

EXPERTS

Mr. Andrew Maynard, Professor, School for the Future of Innovation in Society in Arizona State University, United States

Ms. Ann Kingiri, Senior Research Fellow, African Centre for Technology Studies, Kenya

Mr. Arturo Borja, Deputy Director General, Consejo Nacional de Ciencia y Tecnología (CONACYT), Mexico

Ms. Bitrina Diyamett, Executive Director, Science, Technology and Innovation Policy Research Organization, Tanzania

Mr. Bart Verspagen, Director-Dean of the Maastricht Graduate School of Governance (MGSoG) at Maastricht University and Director of United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT)

Mr. Carlos Casasús, Director General, Corporación Universitaria para el Desarrollo de Internet (CUDI), Mexico

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Mr. Carlos Jesús Mercadillo, Aguirre Innovación, Mexico

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Ms. Gabriela Dutrénit Bielous, Professor, Universidad Autonoma Metropolitana, Mexico

Mr. Iasías Elizarrarás, Director, Ministry of Education, Mexico

Mr. Jaime Parada, President, Academia de Ingeniería , Mexico

Mr. James Bessen, Lecturer in Law at the Boston University School of Law, United States (via video)

Mr. Jose Ramon Lopez-Portillo, Professor, Oxford University, United Kingdom

Ms. Julia Tagüeña, Deputy Director General, CONACYT, Mexico

Ms. Laura Palomares, Professor, Institute of Biotechnology, Universidad Nacional Autónoma de México (UNAM), Mexico

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Mr. Luis Alfonso Villa, Instituto Politécnico Nacional (IPN), Mexico

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Ms. Patricia Zúñiga, Executive Director, Academia de Ingeniería, Mexico

Mr. Raymond Torres, Director, International Institute of Labour Studies (via video)

Ms. Rebecca Hanlin, Innovation and Development Specialist for AfricaLics based at African Centre for Technology Studies, Nairobi, Kenya

Mr. Rob Atkinson, President, Information Technology and Innovation Foundation, United States (via video)

Mr. Rolando Cordera, Professor, UNAM, Mexico

Mr. Sergio Alcocer Martínez de Castro, President, México Exponencial, Mexico

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Mr. Xingquan Wang, Associate Professor, Director of Research Center on Knowledge Management and Chief Expert of Think Tank "Creative Economy", Institute of Information Sciences, Shanghai Academy of Social Sciences, China

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Ms. Adriana Carmona, Chief of Department for Exponential Technology, Ministry of Foreign Affairs

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