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Issues Paper

On

Foresight for Digital Development

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1. Introduction

Technological progress is crucial to achieve sustainable growth and development, as recognized by the prominent roles awarded to technology and innovation, research and development, and information and communication technologies (ICTs) in the recently agreed Sustainable Development Goals (SDGs)[1]. The remarkable progress of ICTs in recent decades is widely recognized as a technological revolution that is driving higher productivity and industrial transformation in the economies at the leading edge of ICT innovation. This Issues Paper analyses a number of digital developments namely Big Data, the Internet of Things (IoT), Massive Open Online Courses (MOOCs), 3D Printing[2], and Digital Automation, and their potential long-term effects on the economy, society, and the environment.

These digital developments have the potential to change substantially how goods and services - both physical and digital - are produced and consumed with significant implications for labour markets. This technological development is marked by the convergence of a number of digital developments, including big data, advanced algorithms, the internet of things, and 3D printing.[3] This confluence of digital trends will likely disrupt and transform existing social, political, and economic norms, bringing both opportunity as well as risks for all countries.[4]

Some of these trends were highlighted during the CSTD's 2013-14 priority theme on 'ICTs for Inclusive and Social and Economic Development'. Further, the CSTD identified strategic technology foresight as a useful tool for sustainable development during its deliberations on its priority theme of 'Strategic foresight for the post-2015 development agenda' in 2014-15. Building on the work of the Commission on these priority themes, this paper applies a strategic foresight lens to the digital developments mentioned. Also, this paper responds to the call made by the ECOSOC to the Commission 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[5]. This with a view to help articulating the important role of ICTs, and STI and engineering as enablers in the future post-2015 development agenda.

[1] General Assembly resolution A/RES/70/1 of 25 September 2015 "Transforming our world: the 2030 Agenda for Sustainable Development"

[2] Also known as additive manufacturing

[3] Banning Garrett, "Technology Will Keep Changing Everything— and Will Do It Faster" (Washington, DC: Atlantic Council, July 6, 2015), 10, http://www.atlanticcouncil.org/images/publications/Technology.pdf; Robert A. Manning, "Rising Robotics and the Third Industrial Revolution," Strategic Foresight Initiative (Washington, DC: Atlantic Council, July 15, 2013), 1–2, http://www.atlanticcouncil.org/images/publications/rising_robotics_third_industrial_revolution.pdf; Atlantic Council, "Envisioning 2030: US Strategy for the Coming Technology Revolution" (Washington, DC: Atlantic Council, December 9, 2013), 15, http://www.atlanticcouncil.org/images/publications/Envisioning_2030_US_Strategy_for_the_Coming_Tech_Revolution_web.pdf.

[4] Atlantic Council, "Envisioning 2030: US Strategy for the Coming Technology Revolution," 1. It is important to note that such disruption will likely affect many countries, both those firmly within the Information Society and those outside it. For example, 3D printing (as will be discussed) could radically shift the global geography of manufacturing, potentially impacting prices of products of goods manufactured in geographies that have not yet embraced 3D printing.

[5] Economic and Social Council Resolution 2015/27 of 22 July 2015 "Science, technology and innovation for development"

This introductory section will review foresight as a tool for policy planning, based on insights from the Commission's 18th Session as well as relevant literature, and conclude with a roadmap of the Issues Paper.

What is Technology Foresight?

Technology Foresight is defined as 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[6]. Foresight ideally addresses potential technology long-term scenarios. Foresight is not only a tool for anticipating the future but has been used to proactively shape the future through policy responses and innovative activities, among others. The foresight scenarios are not intended to reflect exactly how reality will unfold. But they serve as useful heuristics for predicting policy responses for a number of different trajectories, specifically with respect to technology. Foresight is an iterative process that adaptively responds to both endogenous and exogenous factors impacting development. Thus, it can help governments be more responsive and targeted in its policy development and planning processes by ensuring that development planning takes assessment of new and emerging technologies.

There are different methodological approaches to technology foresight, including focus groups, the Delphi Method, Simulations, Scenario Building, and Interviews.[7] There are successful examples of developed and developing countries, regions and cities that have used foresight not only to predict the future but to actively shape it (with respect to digital development). These initiatives are a national multi-stakeholder process involving academia, private sector, research institutes, government, financial institutions, and others in determining a technological course that countries can take and priorities they can set. For example, Japan used foresight for national science and technology policy going back to the 1970's, and it is one of the most cited countries in the literature regarding foresight exercises.[8] The emergence of Japan's electronics sector was supported by a foresight process that defined a forward path that was followed up by large investment in training, learning, technological capacity including innovation and industrial development. The success of Japan to contribute to policy planning has not been widely replicated, particularly in developing countries. But the potential for wider use in development policy should be recognized by policy makers in developing countries.

Many unanticipated aspects of the Information Society have emerged since the WSIS Summit 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 come with new developments such as big data, the Internet of Things, artificial intelligence and the digital automation of work, 3D printing, and MOOCs. Given the many dimensions in which fast innovations in ICTs can present development policies with challenges and opportunities, strategic foresight exercises can help in anticipating the forthcoming technological trends and enable the proactive developing of optimal social responses[9].

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[6] Saritas, Ozcan "Strategic Foresight for the Post-2015 Development Agenda," Presentation at UN CSTD Inter-Sessional Panel, 26 November 2014.
[7] Maurits Butter et al., "How Are Foresight Methods Selected?," *Foresight* 10, no. 6 (2008): 62–89.
[8] Saritas, CSTD Presentation
[9] UNCTAD, "Implementing WSIS Outcomes: A Ten-Year Review" (New York and Geneva: United Nations, 2015), 186.

Roadmap of the paper

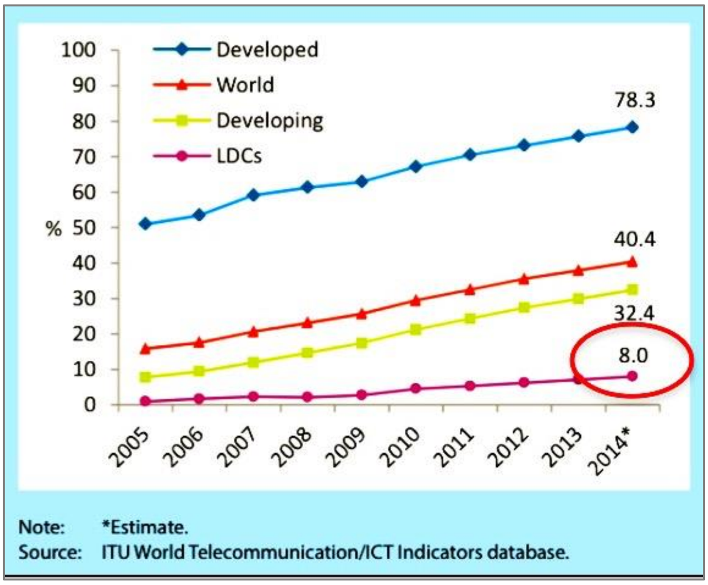
The paper starts with identifying the foundation of all digital developments, which include adequate infrastructure and an enabling environment. Following this discussion, it highlights emerging trends, including big data, Internet of things, Digital Automation, 3D printing, and MOOCs. Each section ends with scenarios that will hopefully serve as heuristics for thinking about and planning for the future. These scenarios are based on literature reviews and reflect differing perspectives on the future of these digital technologies. Along with the scenarios is a summary of key messages for policy makers to consider. The paper ends with policy considerations and a number of questions for discussion at the Inter-sessional panel meeting.

2. ICTs access as a foundation for sustainable development and future digital trends[10]

Digital Divide Remains

During the period spanning 2000-2015, technological advances, combined with market liberalization, have resulted in an explosive growth in mobile networks—both in terms of their coverage and capabilities. 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). Figure 1 reflects the levels of Individual Internet Access during 2005-2014 and how technology advances and market liberalization have generated only modest gains for populations living in the LDCs. For them, digital exclusion remains a reality.

Figure 1: Individual Internet Access



Digital development is key to achieving all 17 Sustainable Development Goals (SDGs). SDG 9c in particular states: "Significantly increase access to information and communication

[10] This section builds on Darrell Owen. "Addressing the Ultimate Digital Challenge." Washington, DC: USAID, September 23, 2015.

technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020." Access to Internet broadband is particularly important and UNCTAD has addressed the key policy challenges and opportunities related to this sector. Many developing countries are facing significant challenges on 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 challenges requires an enabling environment and supportive public policies.[11]

Digital Divide and Future Digital Technologies

Bridging the digital divide and achieving SDG Target 9C are essential prerequisites if countries are to harness the potential of digital developments.

3. Big Data and the Internet of Things

Big data and the Internet of Things are new digital developments that optimize existing business operations as well as make it possible to create new products, services, and entire industries. With the ability to collect unlimited amounts of data through Internet-connected sensors as well as monitor web and social media, it is possible to predict what customers will buy, what income rural citizens have based on their mobile phone activity, or forecast civil unrest in countries. Such technologies add to the existing toolkit for development, but they also introduce particular risks given the availability of fine-grained and increasingly personal data. Given their potential as useful tools for promoting development goals and the risks involved, such technologies deserve attention from policy makers.

This section will define and illustrate what are "big data" and the "Internet of things", and recent and future digital trends as well as their economic impact. The second section will highlight applications of big data and the Internet of things in the areas of enterprise development, healthcare, agriculture, energy and water management, transportation, and statistical indicators for development. In the last section, three scenarios are presented to illustrate how Big Data and the Internet of Things can be used in national development planning.

Big Data

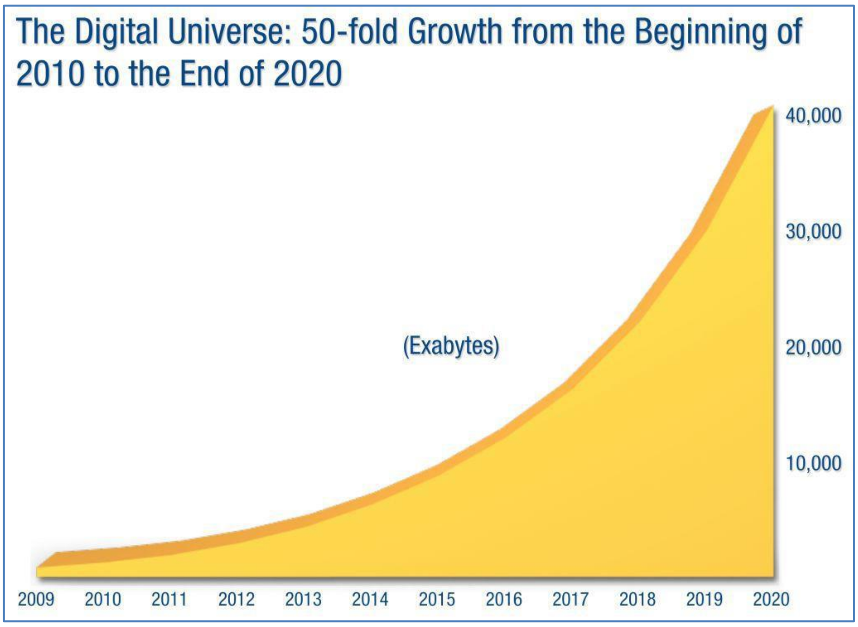
Big data could be defined as

> Huge volumes of data that are created and captured and cannot be processed by a single computer, but rather requires the resources of the cloud to store, manage, and parse... The larger ecosystem of big data includes analysis with the results used to make decisions about the material or online world—whether these decisions are made directly by people or by other machines...[12]

[11] UNCTAD, "Internet Broadband for an Inclusive Digital Society," UNCTAD Current Studies on Science, Technology, and Innovation (New York and Geneva: United Nations, 2015).
[12] Banning Garrett, "Big Data Is Changing Your World... More Than You Know," Strategic Foresight Initiative (Washington, DC: Atlantic Council, September 12, 2013), 3–4, http://www.atlanticcouncil.org/publications/issue-briefs/big-data-is-changing-your-world-more-than-you-know.

It is predicted that data will grow exponentially from around 3 zettabytes in 2013 to approximately 40 zettabytes by 2020 (see Figure 2)[13]. Big data involves creating value in new ways and extracting insights at a large scale that can impact organizations, markets, and government-citizen relationships. The gathering and analysis of big data can be used proactively for administrative and commercial purposes or passively through the digital exhausts of the World Wide Web (web pages and social media), sensor-based devices, and data logs generated by computing devices (see Figure 3).[14]

Figure 2: Growth of Big Data 2010-2020

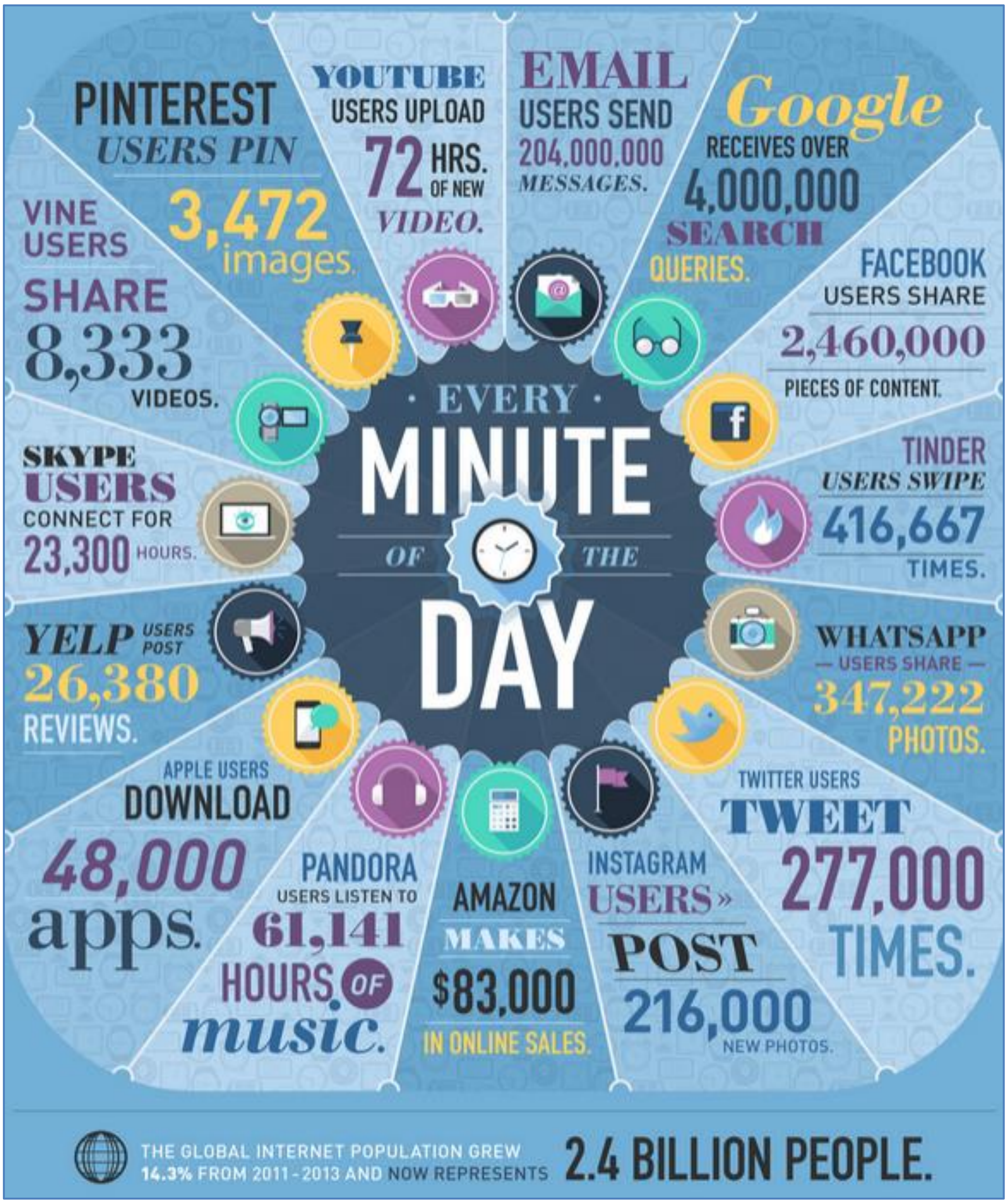


Source: IDC’s Digital Universe Study, December 2012[15]

Big Data analysis can help manage or solve critical global issues, assist in the creation of new scientific breakthroughs, advance human health, provide updated, real-time streams of information on a number of issues (e.g., flu outbreaks or traffic data), monitor the planet's natural systems, improve resource use and efficiency, and support decision-making by business people, policy makers, and members of civil society. The ascendancy of big data is based on the move from sampling data in the small data world to analyzing all of the data. Big data - as opposed to sampled data - makes segmentation and targeting within a dataset more feasible because there is higher availability of information. Figure 3 exemplifies the amount of data generated every minute.

[13] This is an estimate by International Data Corporation (IDC). An exabyte equals 1,000,000,000,000,000,000 bytes and 1,000 exabytes equals one zettabyte.
[14] UNCTAD, “Implementing WSIS Outcomes: A Ten-Year Review,” 77.
[15] http://www.emc.com/collateral/analyst-reports/idc-the-digital-universein-2020.pdf.

Figure 3: Example of Big Data Generated Every Minute of the Day[16]



Internet of Things

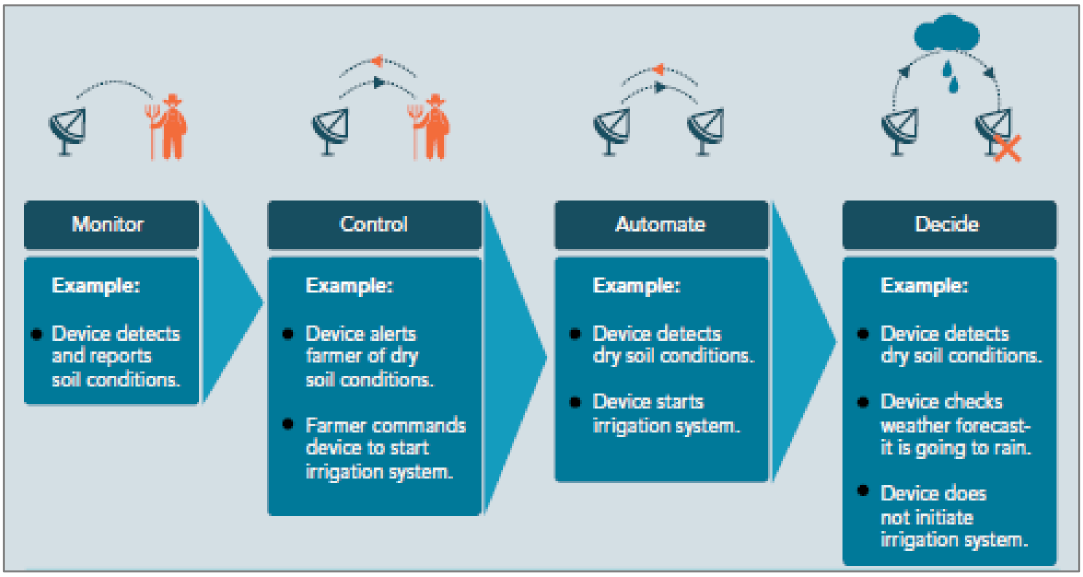
The Internet of Things (IoT) can be defined as "… sensors and actuators connected by networks to computing systems. These systems can monitor or manage the health and actions of connected objects and machines. Connected sensors can also monitor the natural world, people, and animals."[17] In the IoT, objects are connected to the Internet and can exchange data with other connected objects systems and users[18]. Examples of IoT devices include sensor-

[16] https://www.domo.com/blog/2014/04/data-never-sleeps-2-0/
[17] James Manyika et al., "The Internet of Things: Mapping the Value beyond the Hype" (McKinsey Global Institute, June 2015), 1.
[18] http://reliefweb.int/sites/reliefweb.int/files/resources/NetHope_SDG_ICT_Playbook_Final.pdf

based devices that monitor eating, sleeping, or fitness habits, the control of home appliances using mobile phones, or sensor devices for improving agricultural productivity[19].

IoT has the potential to create value in a wide range of sectors including health, retail, construction and trade[20]. Figure 4 shows an example of the range of uses of IoT devices in monitoring soil conditions. These devices allow farmers to monitor soil conditions and decide for instance, when is the best time to plant. In terms of coverage it is expected that the number of devices available will rise from 15 billion in 2015 to 50 billion by 2020, with a third of them being computers, smartphones, TVs and mobile devices. The 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 (see Table 1).[21]

Figure 4: What is the Internet of Things?



Source: SDG ICT Playbook (2015)[22]

The challenges of IoT adoption in general, and especially for developing countries, centre on connectivity (e.g., bandwidth, storage, data centers, etc.), manageability (e.g., uniform architecture and scalable ecosystem), and inter-operability (scalable and easily deployable architecture)[23]. Big data and IoT are potentially synergistic in that the data may come from IoT devices while the IoT devices may effectively function based on big data analysis.

[19] "New to the Internet of Things ? Here's What You Need to Know to Get Started," *Your Story*, August 7, 2015.
[20] James Manyika et al., "The Internet of Things: Mapping the Value beyond the Hype" (McKinsey Global Institute, June 2015), 3
[21] "New to the Internet of Things ? Here's What You Need to Know to Get Started"; "Cyber Gear Launches IoTonlinestore.com, The First IoT Smart Products Store In The Middle East," *Middle East North Africa Financial Network*, September 2, 2015; "Three Challenges In IoT Adoption," *CXOtoday.com*, August 17, 2015; James Manyika et al., "The Internet of Things: Mapping the Value beyond the Hype" (McKinsey Global Institute, June 2015), 7.
[22] http://reliefweb.int/sites/reliefweb.int/files/resources/NetHope_SDG_ICT_Playbook_Final.pdf
[23] "Three Challenges In IoT Adoption."

Table 1: Potential economic impact of IoT in 2025 [24]

Low estimate / High estimate

Size in 2025[1]
$ billion, adjusted to 2015 dollars

Total = $3.9 trillion–11.1 trillion

Settings	Size in 2025 ($ billion)	Major applications
Human	170–1,590	Monitoring and managing illness, improving wellness
Home	200–350	Energy management, safety and security, chore automation, usage-based design of appliances
Retail environments	410–1,160	Automated checkout, layout optimization, smart CRM, in-store personalized promotions, inventory shrinkage prevention
Offices	70–150	Organizational redesign and worker monitoring, augmented reality for training, energy monitoring, building security
Factories	1,210–3,700	Operations optimization, predictive maintenance, inventory optimization, health and safety
Worksites	160–930	Operations optimization, equipment maintenance, health and safety, IoT-enabled R&D
Vehicles	210–740	Condition-based maintenance, reduced insurance
Cities	930–1,660	Public safety and health, traffic control, resource management
Outside	560–850	Logistics routing, autonomous cars and trucks, navigation

1 Includes sized applications only.
NOTE: Numbers may not sum due to rounding.

Big Data and IoT Applications

<u>Enterprise Development</u>

Among other benefits, big data and IoT may help 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. The majority of big data and IoT applications to date have emanated from the private sector taking advantage of these emerging technologies. In fact, (big) data is becoming to the Information Society what fuel was for the industrial economy, powering the innovations of the present and the future[25]. Sales and marketing is being revolutionized by big data analysis as the size and variety of emerging datasets (that capture purchase history, demographics, and real-time location data

[24] McKinsey Global Institute
[25] Mayer-Schönberger and Cukier, *Big Data*, 182.

among other factors) allows companies to divide their customers into granular micro-segments for personalized marketing and cross-selling. Sensor-driven operations help manufacturers optimize operations with highly granular, real-time data from networked sensors in production and supply chain processes[26]. Box 1 describes how big data is used to provide insurance for small scale farmers in Africa.

Box 1: Big Data to Provide Insurance for Small Scale Farmers in Africa

Kenya-based insurance company UAP partnered with Syngenta (farm products provider) and Safaricom (Kenyan telco operator) to launch the Kilimo Salama (Safe Farming) micro-insurance project. Historically, insurance has had many challenges in the Kenyan context including spam advertising through the mobile phone, difficulties claiming insurance money, aggressive, large sales teams and inefficient claims processes. Based on big data from over three decades of climate and crop trends, UAP can determine the appropriate compensation plan for the current year without the need to assess individual cases. This weather index insurance scheme can automatically process insurance claims when the rainfall exceeds an average within the data. As the first micro-insurance product in the world to be fully distributed and implemented over a mobile phone network, farmers can receive insurance policy numbers and premium receipts via SMS and insurance payouts via the M-PESA platform. The project was spinout as the company Acre Africa and in 2014 insured a total of 233,795 farmers in Kenya and Rwanda[27].

The entry barriers to firms presented by access to capital for investment are relatively low. Also, many of the big data technologies, software, and platforms are also open source, reducing the market power of proprietary big data producers[28,29] Furthermore, many big data companies take advantage of cloud computing to virtually store, access, and analyze datasets, minimizing the need to setup and install expensive server equipment.[30] However, issues regarding privacy concerns, security of transactions, and location and storage of data may hinder the deployment or sustainability of these technologies. These challenges may be especially significant in developing countries in which reliability and security of connections are limited. This highlights the importance of establishing institutions and regulations as part of the ecosystem needed to reap the benefits of these emerging trends.

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[27] IFC. "Kilimo Salama (Safe Farming) Weather Index Insurance in Kenya: Early Market Success", Washington, DC: IFC/World Bank, n.d., Source: www.ifc.org; Macharia, Joel, "Abacus Africa-focused Money and Business Data Research Service: Business by the Numbers - Using real time news, data and analytics to make smarter, faster, more informed business decisions in Africa." In Session on "Africa Digital Money & E-commerce User Research Studies & Platforms" at Afrikoin Conference, Nairobi, 20 November 2013. Video Presentation available at: http://www.afrikoin.org/2013.html. Slides are available at: http://www.innovationiseverywhere.com/big-data-africa-insurance-company-provides-optimized-cover-farmers-kenya/. Also see: http://acreafrica.com.

[28] UNCTAD, "Information Economy Report 2012: The Software Industry and Developing Countries," Information Economy Report (New York and Geneva: United Nations, 2012), 2, 4.

[29] Examples of Free and Open Source Software in the Big Data ecosystem include: Hadoop (NoSQL database and distributed computation), Spark (in-memory distributed big data ecosystem), Apache Mesos, R (statistical programming language), Python (general-purpose programming language), and Cassandra.

[30] For more information on cloud computing in developing countries, please see UNCTAD, "Information Economy Report 2013: The Cloud Economy and Developing Countries," Information Economy Report (New York and Geneva: United Nations, 2013).

Healthcare

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. Big data and IoT have many applications in healthcare in these respects. For example, clinical trial design can be improved by applying statistical tools and algorithms by mining patient data and recommending better protocol designs[31]. Also, mapping data can help support response to disease outbreaks. For instance, during a typhoid outbreak, the Uganda's Ministry of Health used mapping data applications to facilitate decision-making on the allocation of medicine and mobilization of health teams (see Box 2).

Box 2: Data Visualization and Interactive Mapping to Support Response to Disease Outbreak in Uganda

In 2015 Uganda had a typhoid outbreak. The Ugandan Ministry of Health's district collected data at the health centres where typhoid cases were treated. In order to effectively use this information for a disease response, Pulse Lab Kampala was invited to utilize interactive data visualization tools to help present dynamic information about case data and risk factors to manage the outbreak. This, in turn, helped reveal clusters of infection through interactive maps at district, sub-county and individual health facility levels. Furthermore, interactive mapping tools provided the ability to show infection rate data along with information about risk factors, therefore helping health workers to better understand the patterns of disease transmission. As a result, the visualizations contributed to decision-making process regarding the allocation of medicine and mobilization of health teams[32].

Big data and IoT have also been applied in medical research. For instance, researchers from the Institute for Computational Health Sciences are using freely available clinical big data released as part of the US National Institutes of Health (NIH) funding requirements to study whether existing drugs could treat other medical conditions.[33]

The promise of Big Data and IoT to address healthcare must balance the privacy, confidentiality and security of patients that are currently standard aspects of clinical care. Confidential health records disclosed to third-parties could potentially impact insurance policies or even future employment prospects. Appropriate regulatory frameworks, as well as professional and organizational standards on the use of data and IoT devices in healthcare, are issues that policy makers may need to address.

[31] Manyika et al., "Big Data: The next Frontier for Innovation, Competition, and Productivity" 2015.
[32] UN Global Pulse, "Data Visualisation and Interactive Mapping to Support response to Disease Outbreak ", Global Pulse Project Series no. 20, 2015
[33] The Institute for Computational Health Sciences was established in 2013 by the University of California San Francisco (UCSF) to harness the power of "big data" to more quickly develop effective cures for patients worldwide

Agriculture

Big Data and IoT are also creating new possibilities in agriculture, and may provide useful tools to increase food security. For instance, in India, the CropIn startup provides analytics and software solutions for crop management. The company develops a vegetation index using satellite imagery that ultimately provides decision support to farmers about do's and don'ts for ensuring crop health (see Box 3).[34]

Box 3: Big Data for Agriculture in India

The company CropIn was created to provide software solutions and analytics for crop management. Today customers for this customised cloud application are large companies that have invested in food processing and agriculture and had to depend heavily on their field staff to connect with farmers. The CropIn application tags crops and tracks its 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, including Pepsico and Mahindra Agri, and benefits 100,000 farmers across 15 states in India.[35]

The questions of information on ownership and data access must be resolved, especially if IoT devices are capturing data. Does such data belong to the farmer, the government or a third-party provider (private or non-governmental)? Furthermore, the privacy policies of private-sector companies involved in the collection, aggregation or analysis of agriculture-related data must be understood, as well as its potential impact on farmer livelihoods.[36]

Energy

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 with solar panels on their roofs or wind turbines to feed surplus energy back into the electricity grid. The real-time information provided by smart grids helps utility companies better respond to demand, power supply, costs, and emissions as well as avert major power outages[37]. For instance, Zenatix, a Delhi-based startup, deploys smart meters and temperature sensors to monitor energy meters and help households and offices reduce energy consumption through message-based alerts. One successful example of their impact is saving IIIT (Indraprastha Institute of Information Technology), Delhi close to $30,000 annually in energy consumption costs[38].

[34] Pratap Vikram Singh, "The Startup Revolution: Smart Solutions for Social Good," Governance Now, August 1, 2015.
[35] (Governance Now, 2015)
[36] One perspective on data privacy and ownership in agriculture can be found here: Russo, Joseph, "Data Privacy, Ownership in Precision Agriculture", PrecisionAg, opinion, 3 September 2013.
[37] UNCTAD, "Science, Technology and Innovation for Sustainable Urbanization," UNCTAD Current Studies on Science, Technology, and Innovation (New York and Geneva: United Nations, 2015), 23.
[38] "Will Energy and Water Challenges Propel an IoT Wave in India ?," *Your Story*, July 20, 2015.

The use of big data and the IoT in energy must be balanced by an understanding of the associated privacy implications related to the household and their use patterns. Sophisticated statistical algorithms that utilize smart meter data can determine sensitive household information like which appliances or devices a household might have and when it is operating. There should be organizational and regulatory standards for how such data is collected, processed, and shared.

Water Management

Like energy, the production and efficient distribution of water, especially in urban areas, is a perennial challenge for national, regional, and local governments. IoT devices like sensors, meters, and mobile phones can be tapped for smarter water management (see Table 2). The role of IoT devices in water management is highlighted in the table below. However, similar to the case of energy, the collection, analysis, and sharing of data on water usage must balance the privacy, confidentiality, and security considerations. The case study below (see Box 4) describes the application of a wireless sensor network to monitor and study the water quality in Bangladesh.

Table 2: Major areas for IoT devices in water management[39]

Mapping of Water Resources and Weather Forecasting • Remote sensing from satellites • In-situ terrestrial sensing systems • Geographical Information Systems • Sensor networks and the Internet	**Asset Management for the Water Distribution Network** • Buried asset identification and electronic tagging • Smart pipes • Just in time repairs/real time risk assessment
Setting up Early Warning Systems and Meeting Water Demand in Cities of the Future • Rain/storm water harvesting • Flood management • Managed aquifer recharge • Smart metering • Process Knowledge Systems	**Just in Time Irrigation in Agriculture and Landscaping** • Geographical Information Systems • Sensors networks and the Internet

Box 4: Water Quality Monitoring using IoT: Bangladesh

In Bangladesh tens of millions of people in the Ganges Delta are faced with the threat of drinking ground water that is contaminated with arsenic. Testing and analysis of arsenic contamination is found to be technically difficult and expensive[40]. IoT can be a life saver in this context. Wireless Sensor Networks (WSN) was deployed, mainly to facilitate better understanding of the factors controlling arsenic mobilization to ground. A manual arsenic sensor, combined with the data collected from the sensor network, has been used to get a better understanding of the groundwater chemistry at shallow depth. Scientists associated with this project recommended that WSN be deployed as a shared resource in developing countries to address critical development al challenges[41].

[39] Ibid.
[40] http://www.worldwatch.org/node/529
[41] http://users.ictp.it/~mzennaro/WSN4D.pdf

Statistical Indicators for Social and Economic Analysis

Collecting and measuring development indicators will be key to monitor the progress towards achieving the Sustainable Development Goals. [42]International organizations, researchers, and private sector companies are harnessing big data as statistical indicators for development. [43] IoT devices, along with big data hosted on the Web, may provide new opportunities for measuring statistical and economic indicators for development. For instance, a study carried out by the UN World Food Programme (WFP) used mobile data to assess food security. The results showed that airtime could serve as a proxy indicator for marketplace food expenditures (see Box 5). Research has also examined the predictive power of web search data to predict social and economic trends. For instance, it has been found that Google Trends (real-time daily and weekly index of the volume of queries that users enter into Google) query indices often correlated with various economic indicators and that may be helpful for short-term economic predictions. [44] However, it remains to be seen whether these big data-derived indicators will continue to be as accurate as research and pilot projects suggest. They may hold the potential of creating additional tools to measure and evaluate progress towards sustainable development goals. At the same time, the veracity and accuracy of Big Data and IoT derived data must be continuously monitored. Big data algorithms should not be taken at face value but critically examined, especially when used as part of complementary indicators for development efforts. This highlights the importance of human capabilities to assess and evaluate the accuracy of big data algorithms and understand when the results are useful or misleading. This also could point to the need for human resources able to understand the implications of such indicators.

Box 5: Big Data for Estimating Food Security in Rwanda[45]

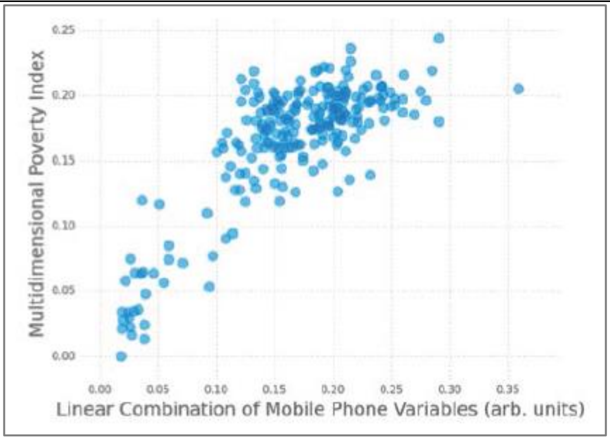
A study assessed the potential use of mobile phone data as a proxy for food security indicators was carried out by WFP and Université Catholique de Louvain and Real Impact Analytics of Belgium. Data from airtime credit purchases (or "top-ups") and mobile phone activity in an East African country was compared to a nationwide household survey conducted by WFP at the same time. Results showed high correlations between airtime credit purchases and survey results referring to consumption of several food items, such as vitamin-rich vegetables, meat or cereals. Findings demonstrated that airtime purchases could serve as a proxy indicator for marketplace food expenditures. In addition, models based on both mobile phone activity and airtime credit purchases were shown to accurately estimate multidimensional poverty indicators. Proxies like these could be usefully integrated into existing monitoring systems. The Figure below shows the correlation between the Multidimensional Poverty Index and a combination of mobile phone variables (including top-ups.)

[42] General Assembly resolution A/RES/70/1 of 25 September 2015 "Transforming our world: the 2030 Agenda for Sustainable Development"

[43] e.g., UN Statistical Commission and UN Global Pulse

[44] Hyunyoung Choi and Hal Varian, “Predicting the Present with Google Trends,” *Economic Record* 88, no. s1 (2012): 2–9.

[45] UN Global Pulse, "Annual Report" (2014): 8



Considerations related to Big data and IoT

So far this paper has discussed the potential applications of Big Data and IoT for economic and social development. These emerging technologies can contribute to manage and potentially solve critical issues at the global, regional, national, and local levels and have cross-sectoral applications. There are, however, several considerations and challenges that stakeholders, especially policymakers, need to address in order to exploit their potential. The rest of this section discusses some of these issues, namely national development planning, regulatory frameworks, and deepening human capacity.

Big data and causality of effects

Big data analysis is frequently used to predict what will happen but not why it happens. Since the data is frequently used for correlation analysis, it is unsuitable for judging causality. Because humans see the world as cause-and-effect, correlational conclusions from big data can be used to support faulty causal assumptions, leading to incorrect inferences about actions to take and the system that is being measured[46]. With some online big data applications it is unclear whether "big data" algorithms make the best matches based on valid statistics or whether people adapt to information systems, expecting them to make good matches. [47]

Furthermore, big data is fundamentally about the past and its usefulness is reduced when the state of the world changes radically from the conditions that existed when the data were collected. Thus, big data is only accurate and useful for decision-making processes if it can constantly update our understanding of the world[48].

Integrate Big Data and IoT into National Development Planning

Policymakers may consider how they can use Big Data and the IoT as tools for achieving national development goals. For instance, Box 6 discusses a partnership project between the United Nations Development Programme (UNDP) and other stakeholders aimed at harnessing Big Data to support development goals. As shown earlier, Big data and IoT applications

[46] Mayer-Schönberger V and Cukier KN (2013). *Big Data : A Revolution That Will Transform How We Live, Work, and Think*. Houghton Mifflin Harcourt. Boston, Mass, p. 163.
[47] Lanier J (2013). *Who Owns the Future?* Simon & Schuster. New York. p. 113.
[48] Hilbert M (2015). E-science for digital development: "ict4ict4d." Development Informatics Working Paper Series No. Paper No. 60. Centre for Development Informatics. Manchester, UK.

could contribute to sustainable development at national, regional, and local levels. For example, IoT devices can be used to enhance city infrastructures, contributing to more effective and environmentally-sustainable transport, housing, water, sanitation, and construction.

Box 6: Harnessing big data to support development goals

In 2014 a collaborative initiative the Big Data Joint Laboratory was launched as a partnership between the UNDP, China, and Baidu to harness big data for achieving development goals. Stakeholders representing development and big data experts from UNDP, Baidu, the private sector, government, academia, and civil service organizations are expected to use the lab to produce idea prototypes for testing and implementation. Baidu's Big Data engine will be used to identify which data has promise for the formulation and implementation of development strategies. An inaugural product of the lab is an e-waste recycling "Light App" that helps streamline electronic waste recycling[49].

By collaborating with different stakeholders, Governments may consider developing a 'National Big Data Strategy' on how they plan to harness the potential of big data towards national development. Sectoral policies across governments (e.g., agriculture, education, fisheries, water, sanitation, etc.) may consider whether and how their existing plans and strategies can be enhanced with the use of Big Data and IoT devices. The following case study from Malaysia describes how governments can integrate Big data analysis into national strategies, forming a clear big data strategy and linking the same with the overall national development frameworks (see Box 7). Further, governments may consider hiring data scientists and creating cross-sectoral units that apply big data and IoT to problem-solving across a range of applications. For instance, in the past few years, countries such as Singapore and the United States have created Chief Data Scientist positions at the national level. Many cities are also creating Chief Data Scientist or Chief Data Officer positions to use or to harness data at the city levels to improve internal government process as well as services to citizens.

Box 7: National Big Data Analysis (BDA) Initiative, Malaysia

Malaysia launched its National Big Data Analysis Initiative in 2014 with an aim to transform Malaysia into a leading regional BDA hub. This initiative is linked with the Digital Malaysia Program (the national ICT strategy of Malaysia). Objectives of the initiative are to (i) proliferate the use of BDA in all sectors (ii) catalyse the usage of BDA in public sector (iii) Build the BDA industry. To achieve these goals, short term, medium and long term policy actions have been identified. The short terms actions include developing a BDA framework and kick starting government pilot projects in BDA. Five main roles to be played by government have been identified, namely, (i) open and shared data policy (ii) Education (iii)Infrastructure (iv) Funding and (v) regulatory (removing barriers to BDA innovation). In early 2015, a BDA Innovation Network was launched and three MoU's were signed with

[49] UNDP. 2014 Annual Review UNDP Innovation Facility. New York: UNDP. 2014. Also, see: http://www.cn.undp.org/content/china/en/home/presscenter/pressreleases/2014/08/harnessing-the-power-of-big-data/.

leading industry and key government partners to establish a network of BDA Innovation Centres of Excellence[50]. In May 2015, a Big Data Digital Government Lab was also launched to become the hub for BDA technologies for public sector [51].

Create Regulatory Frameworks for Big Data and the Internet of Things

With the increasing availability of data from big data applications and IoT devices, there is a need to consider how best to regulate the sharing and use of data. The increasing ubiquity of personal data available to commercial and government entities based on Internet usage and IoT devices presents difficulties with respect to privacy and security. The UN High Commissioner for Human Rights' report on *The Right to Privacy in the Digital Age* warns of "a lack of adequate national legislation and/or enforcement, weak procedural safeguards, and ineffective oversight" with respect to the right to privacy[52].[53] In particular, privacy and security are hard to ensure because of individual notice and consent, opt-out policies, and anonymization, among others issues related to IoT devices.[54] Therefore, a regulatory framework for data collection, usage, and access may be considered. Government can also play a role in developing standards for the interoperability of big data and data from IoT devices.[55]

Deepen human capital through digital education and skills development

There is a need for building human capacity to take advantage of the new digital developments as well as minimize its risks. The shortage of analytical talent in computer science, statistics, machine learning, and Internet of Things - as well as the managers and analysts to understand how to run digital organizations - will constrain the potential of big data and IoT across sectors.[56] According to some estimates, by 2018 there will be a shortage of 140,000-190,000 people with deep analytical skills as well as 1.5 million managers and analysts who can leverage big data for decision-making.[57] Beyond technical professionals and data-savvy managers, government stakeholders and policymakers may also benefit from training on the potential benefits and risks of such technologies in order to inform development planning and policy making.

Initiatives aimed at strengthening domestic capabilities may help a range of actors - firms, research institutes, universities, and government-related organizations. One example is the Addis Artificial Intelligence (AI) Lab in Ethiopia that works with local universities, schools, and the government and provides open-source programming to the community. The AI lab focuses on a number of different areas of AI, including: machine learning based data analysis, computational linguistics, computer vision, mobile robots and cognitive robotics, cognitive architectures and artificial general intelligence[58]. Another way of creating local capacity in

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[50] http://www.digitalmalaysia.my/newsroom/news/news-releases/mdec-launches-national-big-data-analytics-bda-innovation-network
[51] http://www.mimos.my/paper/malaysias-big-data-drive-continues-mimos-launches-national-lab/
[52] UNCTAD, "Implementing WSIS Outcomes: A Ten-Year Review," 30.
[53] Report is available at:
http://www.ohchr.org/EN/HRBodies/HRC/RegularSessions/Session27/Documents/A.HRC.27.37_en.pdf
[54] Mayer-Schönberger and Cukier, *Big Data*, 6.
[55] McKinsey Global Institute "The Internet of Things: Mapping the Value beyond the Hype" (pp. 12-13)
[56] Manyika et al., "Big Data: The next Frontier for Innovation, Competition, and Productivity."
[57] Banning Garrett, "Big Data Is Changing Your World... More Than You Know," 7.

big data analysis is through engaging in research partnerships with global counterparts. The success story of South Africa in this context is discussed in the case study below (see Box 8).

Box 8: Promoting Skills in Big Data Analytics through Global Partnerships: South Africa

The South Africa Department of Science and Technology (DST) launched the Centre for High Performance Computing (CHPC) in 2007. The CHPC engages in the training of data scientists, supports research projects that use big data sets, and provides opportunities for researchers to participate and collaborate with international networks. The South African Research Network (SANReN), a large-scale, high capacity National Research and Education Network, which is closely linked to the CHPC, provides cyber infrastructure for big data amongst the South African universities. SANReN in collaboration with the Tertiary Education Research Network of South Africa (TENET) connected most South African universities to fibre cyber infrastructure leading to excellent Internet speeds for students with a focus on research data. South African researchers engage in big data partnerships that include international public and private institutions (e.g. the UK Cambridge partnership and membership of the two experiments at the Large Hadron Collider ATLAS and ALICE at CERN). A number of institutional based activities are being deployed in support of big data as an enabler for research activities. For example the Human Heredity and Health in Africa (H3Africa) research platform focus on bioinformatics in collaboration with Cambridge[59].

Strengthen Big Data and IoT ecosystems

In addition to a trained work force, effective applications of IoT and Big data will require a whole array of supportive infrastructure and enabling policy frameworks, such as cloud computing resources and standards of interoperability. All these associated components constitute the IoT and Big data ecosystems. Governments need to continuously monitor and evaluate the effectiveness of their national big data and IoT ecosystems. This will help to identify the weaker components of the ecosystem and allow Governments to address them through policy actions. These ecosystems are likely to be weak in LDCs, low income countries, and smaller developing countries.

Scenarios for Big Data, IoT, and Development

Table 3 presents three potential scenarios with respect to Big Data and the Internet of Things for the purposes of sustainable development.

Table 3: Big Data and IoT Scenarios

Scenario	Description
(1) Big Data and IoT playing marginal role implementing the development agenda	This scenario represents the status quo, where most data for development comes from national statistical offices, web, and IoT data are rarely considered as part of sustainable development agenda.

[59] Source: https://globalstatement2015.wordpress.com/2015/09/23/big-data-in-south-africa/

(2) Big Data and IoT as significant means of implementation of the development agenda	Various stakeholders harness big data and IoT to provide up-to-date statistical indicators for development, improve health outcomes, target policy interventions, and make government more transparent and accountable. Existing companies use big data for market segmentation, improving supply chains, making manufacturing more productive, etc. Agricultural productivity is improved through IoT sensors as well as big data analysis incorporating weather, ecological, and related data.
(3) Big Data and IoT radically reshaping the practice of development	Big data and IoT applications are used to radically change development strategies. Predictive policing pre-empts potential civil crimes and social conflict with potential violent consequences. IoT data (through mobile phones) and big data analytics predict who is likely to experience a financial shock. Big data and IoT are the foundations of companies in completely new industries. Food insecurity is forecasted and food is prepositioned for distribution as required. Health authorities predict when someone will get diseases (such as malaria) and proactively provide medicines.

4. 3D Printing

Another recent digital development along with Big Data and the Internet of Things is 3D printing. In fact, all these technologies represent the ways in which “datafication” and digitalization are enabling ways to model and predict the world with massive amounts of data (Big Data), sense and control aspects of the world through new internet-connected devices (IoT), and create real-world artifacts and products (3D printing). 3D printing offers potential economic, social and environmental benefits for developing countries. The potential benefits of 3D printing are making it an increasingly important issue for policymakers across the world to consider. However, 3D printing may not necessarily mature into a technology that radically reshapes the economy or environment, and it could present risks as physical products - like weapons - are digitized. This section defines what 3D printing is, discusses its potential applications across a number of domains (e.g., enterprise development, environment, water, sanitation, agriculture, food, construction, healthcare, and education), and provides several scenarios for the impact of 3D printing on economies in the next 10-15 years.

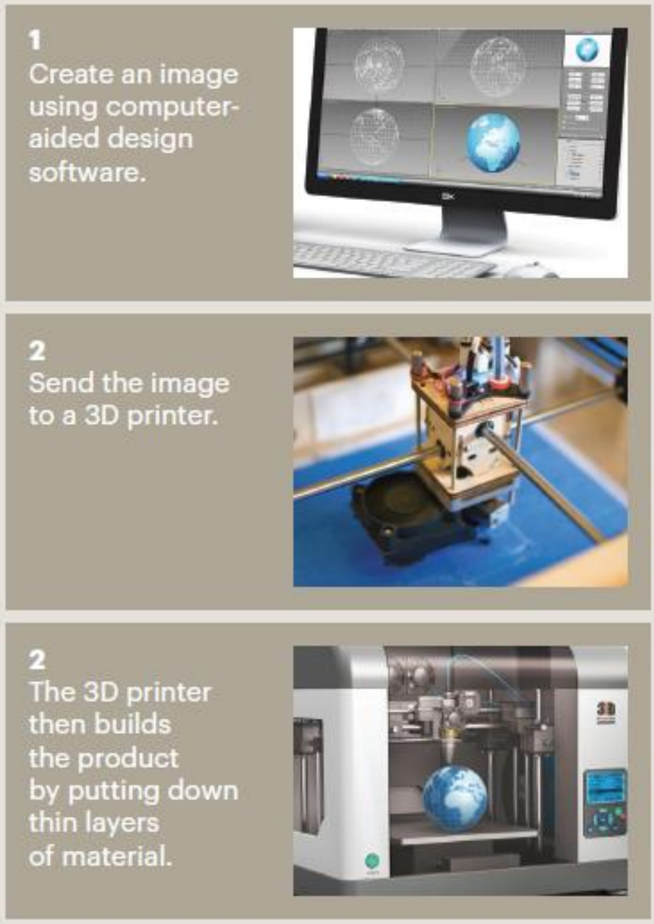
What is 3D printing?

3D printing is "...the production of physical items layer by layer, in much the same way an inkjet printer lays down ink..."[60] Though 3D printing was invented about three decades ago, huge reductions in its costs along with complementary developments in computer-aided design, the Internet, new materials for manufacturing, and cloud computing have made 3D printing a viable technology for global manufacturers to produce critical parts for airplanes, wind turbines, automobiles, and other machines.[61] Instead of traditional (subtractive) manufacturing that carves parts out of raw materials, 3D printing - also known as additive

[60] Cohen, Daniel, Katy George, and Colin Shaw. "Are you ready for 3-D printing?", McKinsey Quarterly, February 2015, p. 1
[61] Banning Garrett, “Technology Will Keep Changing Everything— and Will Do It Faster,” 9.

manufacturing - uses a simple process of layering to make things (see Figure 5).[62] 3D printing typically takes a long time as layers of resin (or other materials) are printed over and over again. However, new methods are emerging to speed up this process by as much as 100 times[63]. Not only global manufacturers, but tens of thousands of early adopters, are now experimenting with 3D printers or starting their own mini-manufacturing enterprises.[64]

Figure 5: What is 3D Printing?[65]



Technology	Material type
Photo-polymerization	• Plastics • Ceramics and wax
Material extrusion	• Plastics • Sand
Sheet lamination	• Plastics • Metals
Binder jetting	• Plastics • Metals • Glass
Material jetting	• Plastics • Metals • Wax and biomaterial
Powder bed fusion	• Plastics • Metals • Ceramics, sand, and carbon
Direct energy deposition	• Metals

As a "platform technology", 3D printing can be used in a range of applications, including health care (e.g., printing human organs), food (e.g., printing food), aerospace (e.g., printing airplane parts), construction (e.g., printing houses, large buildings, and even bases on Mars and the moon).[66] It has been argued that in the developing world 3D printing can help countries leapfrog into manufacturing and produce large numbers of products on demand with retooling while using recycled materials and less costly infrastructure.

Figure 6: The use of 3D printing is expected to grow[67]

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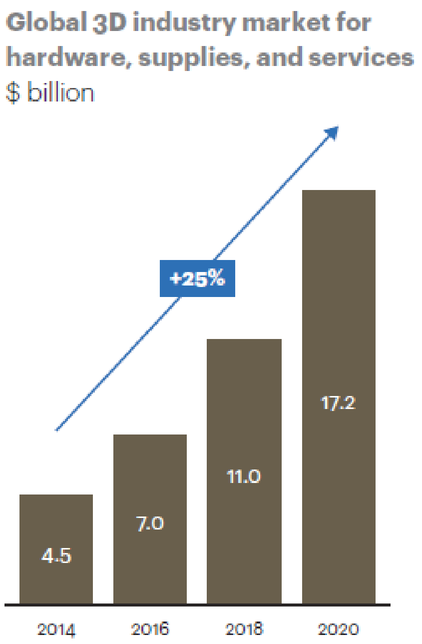
[62] Atlantic Council, “Envisioning 2030: US Strategy for the Coming Technology Revolution,” 15.
[63] James Cumming, “Should Namibia Embrace 3D Manufacturing?,” *The Namibian*, April 28, 2015.
[64] Atlantic Council, “Envisioning 2030: US Strategy for the Coming Technology Revolution,” 15–16.
[65] Source: AT Kearney, "3D Printing, A Manufacturing Revolution"
[66] Atlantic Council, “Envisioning 2030: US Strategy for the Coming Technology Revolution,” 16.
[67] Wohlers Report, SmarTech Markets, Credit Suisse; A.T. Kearney Analysis



3D printing market

Sector	2014	Five-year CAGR
Aerospace (including defense)	$0.8 billion 18%	15–20%
Industrial (including construction)	$0.8 billion 18%	15–20%
Healthcare	$0.7 billion 15-17%	20–25%
Automotive	$0.5 billion 12%	15–20%
Jewelry	$0.5 billion 12%	25–30%
Energy	Less than 5%	30–35%
Other (many sectors)	Less than 20%	20–25%
Total	**$4.5 billion**	**25%**

The 3D printing market is expected to grow quickly in coming years (see Figure 6). According to Gartner estimates, 3D printer shipments should at least double every year between 2015 and 2018, reaching 2.3 million units by that time[68]. The Wohlers Report 2014 claims that 3D printing revenues will jump from $3.07 billion in 2013 to $12.8 billion 2018 and more than $21 billion by 2020[69,70].This growth will not only happen in developed countries but also developing countries. Allied Market Research has forecasted that 3D printing in emerging economies will experience growth of 37.4% over 2014 to 2020 to reach a $4.5 billion market by 2020. They expect India and China to lead among emerging economies[71]. For example, in India the 3D printer market could register $79 million by 2021[72].

Potential Applications of 3D Printing

3D printing presents a number of potential benefits, especially for developing countries and in the context of the sustainable development goals.

<u>Enterprise Development</u>

[68] Business News Americas, "3D Systems to Build LatAm's Largest 3D Printing Park' in Brazil," *Business News Americas*, June 5, 2015.
[69] Rajat Ubhaykar, "The Emerging World Of 3D Printing," *Outlook Business (India)*, March 6, 2015, sec. Miscellaneous.
[70] Wohlers Associates, Inc. is considered an authoritative source of information on the additive manufacturing market. Alternatively, Scarlett Inc. forecasts that the 3D printing industry will grow to more than $17 billion in 2020 from the $3.8 billion in 2012 Charlsie Dewey, "Industrial Equipment Distributor Focuses on 3D Printing," *Grand Rapids Business Journal* 33, no. 25 (June 22, 2015): 20..
[71] PRWeb, "3D Printing Market in Emerging Economies Is Expected to Reach $4.5 Billion by 2020 - Allied Market Research," *New Vision*, April 22, 2015.
[72] http://www.researchandmarkets.com/reports/3147967/india-3d-printer-market-2015-2021-market

Many parts of the world do not have significant manufacturing capability and rely on massive imports of consumer goods. Although 3D printing is a niche technology, 3D printing facilities could open up opportunities for production at significantly cheaper costs that were previously only available through a conventional factory.[73] In both developing and developed countries, 3D printing has the potential of transforming business, especially in the manufacturing sector (see Box 9). The transforming potential of 3D printing technologies on business can be explained by three main elements. First, it provides both cost and time savings for the production of parts that are typically created by traditional tool-and-die processes. Second, 3D printing can be used to manufacture complex, low volume parts and products, especially in sectors like aerospace.[74] Third, 3D printing allows for rapid, iterative prototyping within enterprises that involve manufacturing. However, there are several limitations with respect to enterprises use of 3D printing. The cost savings are potentially eroded when engaged in high-volume manufacturing. It is also relatively slow compared to traditional manufacturing with a limited range of printing materials.[75] Therefore the benefits from 3D may be limited to specific industrial activities.

Box 9: Examples of 3D Printing

In one example, 3D printing has been applied to cost-efficient production in the automotive industry. The Chinese company Sanya Si Hai 3D has produced a two-seater compact sedan that can reach speeds of 40 kmph (see picture below). It took only $1,700 and five days to build this car.

Also Tata Motors has incorporated 3D printing technologies in their processes to reduce its turnaround times from months to weeks and thus iterate more in design. Instead of handing off computer aided design (CAD) models to manufacturers who use traditional machinery, the

[73] Atlantic Council, "Envisioning 2030: US Strategy for the Coming Technology Revolution," iv.
[74] Rajat Ubhaykar, "The Emerging World Of 3D Printing"; Pratima Harigunani, "Google Glass or Hololens, There's Many a Slip - Between the Labs and Enterprise Cups, There's a Distance That Gets Meaner and Longer with Every New Idea That Catches Tech World's Fancy. If You Thought You Will Soon See That Sci-Fi Glass by Your Boss's Side or Those 3D Printed Cars in Your Office Parking, You Really Need to Read This," *CIOL*, February 25, 2015.
[75] McCutcheon, Robert, "Limitations of 3D printing", PWC Industrial Insights, 24 March 2014.

CAD models are used directly to 3D print parts and validate designs that are difficult to visualize on a 2D screen[76].

Change and Sustainability

Environmental degradation and climate change are amongst the biggest threats to humanity requiring the decoupling of economic growth from greenhouse gas emissions and wasteful resource use[77]. 3D printing technologies could potentially contribute to such a decoupling. Because 3D printed products are produced in just one process, the multitudes of parts traditionally required to construct some products will no longer need to be traditionally manufactured and transported, thus decreasing carbon emissions[78]. 3D printing only uses the material it needs instead of conventional manufacturing where material is removed and often recycled[79]. Further, 3D printing technologies could also contribute to reduced CO2 emissions. Estimates have shown that CO2 emissions intensities of industrial manufacturing could be reduced by up to 5% by 2025 if 3D printing remains a niche technology. However, 3D printing has the (theoretical) potential to decouple energy and CO2 emissions if it were applicable to larger production volumes in consumer products or automotive manufacturing.[80] However, other potential environmental implications of 3D printers must be considered, including their propensity to consume more electrical energy than other forms of manufacturing (e.g., injection molding), unhealthy air emissions (especially in home environments), and an increased reliance on plastics.[81] Ultimately, if 3D printing is to contribute to more sustainable development, it will require concerted efforts to innovate so as to maximize the potential environmental benefits and minimize the associated environmental costs

Building construction

The rapid rate of urbanization, especially in developing countries, requires new approaches to cost-effective and sustainable housing. 3D printing is being used to inexpensively and quickly construct buildings in demonstration experiments across the world. In China, 3D printed homes are being built. For example, in an industrial park in Jiangsu province a five-story house was created using a 21ft tall, 32ft wide and 500ft long 3D printer. Its "ink" was a mixture of glass, steel, cement, and recycled construction waste[82]. Another example, from a research centre in China shows that using 3D printing technologies it would be possible to build a three-story house made of recycled materials in three days[83,84]. The advantages of 3D

[76] Rajat Ubhaykar, "The Emerging World Of 3D Printing."
[77] UNCTAD, "From Decisions to Actions: Report of the Secretary-General of UNCTAD to UNCTAD XIV" (New York and Geneva: United Nations, 2015), 8, http://unctad.org/en/PublicationsLibrary/unctad_xivd1_en.pdf.
[78] Fredrick R. Ishengoma and Adam B. Mtaho, "3D Printing: Developing Countries Perspectives," *International Journal of Computer Applications (0975 – 8887)* 104, no. 11 (October 2014): 33.
[79] Charlsie Dewey, "Industrial Equipment Distributor Focuses on 3D Printing."
[80] Malte Gebler, Anton JM Schoot Uiterkamp, and Cindy Visser, "A Global Sustainability Perspective on 3D Printing Technologies," *Energy Policy* 74 (November 1, 2014): 158.
[81] Gilpin, Lyndsey. "The dark side of 3D printing: 10 things to watch", *TechRepublic*, 5 March 2014.
[82] Steph Cockroft, "Digital Plan to Save Ancient Sites from ISIS Ruin: 'Monuments Men' Believe 3D Printers Could Rebuild Archaeological Treasures Destroyed by Jihadists in the Middle East," *Mail Online*, August 28, 2015, sec. News.
[83] 3D Research Printing Institute, Nanjing, China.
[84] Saudi Press Agency, "Entrepreneurs Find New Ways to Address Housing Shortages," *Saudi Press Agency*, April 11, 2015.

printing include more accurate and fast construction of buildings as well as reduced labor costs, waste generation, and health and safety risks. But it is necessary to consider the potential effects of 3D printing on the number of people employed in the construction industry, on the type of materials used to construct buildings, and on the final product in case errors in digital model are translated into printing and construction.[85] As a result, it is important for policymakers when considering 3D printing as a tool to address housing and urbanization to include issues of cost and construction time along with the potential employment implications.

Healthcare

One of the potential applications of 3D printing technologies in the healthcare sector, especially in developing countries, is on the development of low cost prosthetics 3D printing, potentially making low-cost prosthetics a reality for a number of medical applications. For example, South Africa's Centre for Rapid Prototyping and Manufacturing (CRPM) at the Central University of Technology, Free State (CUT) has 3D printed titanium jaws for at least a dozen patients at Kimberley Hospital[86]. However, 3D printing in some cases may not be ideal for prosthetics. Prosthetic limbs are generally made of a combination of materials whereas, so far, most 3D printers can only print one material at a time. Furthermore, 3D printed models may not be able to reconstruct the interface between the prosthetic limb and the soft tissue to which it must securely attach.[87] It is important to understand these tradeoffs especially if such innovations are being considered as part of healthcare initiatives at the national or local levels.

Education

Education could potentially be enhanced if abstract concepts are made concrete for students to explore. In this regard, 3D printing is being used as a tool for education in primary, secondary, and post-secondary schools. In the USA, for example, some 3D printing companies are training educators in the use of the technology as part of afterschool programs at their schools[88]. In India, students are 3D printing historical artifacts, organ parts, cities, art projects, and dinosaurs to get hands-on experience about various subjects[89]. In addition, collaborative efforts between private firms and non-profit organizations are showing positive results in digitizing diagrams and educational images in school textbooks for the visually impaired through 3D models of concepts that can be "visualized" by touch in a cost-effective way.[90] Even though 3D printing can play a role in improving some educational environments, integrating 3D printers into education also requires upgrading of the capacities of teachers. Teachers would need to understand how to create and print 3D models as well as assess the suitability of such technology to existing learning strategies. Box 10 describes fabrication

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[85] Husseini, Adam. "3D printing and the construction industry", NBS, November 2014. Link: http://www.thenbs.com/topics/ConstructionProducts/articles/3d-printing-and-the-construction-industry.asp

[86] Diamond Fields Advertiser, "CUT Takes Lead in 3D Printing for Medical Purposes," *Diamond Fields Advertiser*, August 21, 2015, sec. E1; "S/ African Doctors Perform First 3D-Printed Jaw Implant," *APANEWS*, July 25, 2014.

[87] Andrews, Travis M. "Can we Really 3-D Print Limbs for Amputees?", *The Atlantic*, 23 August 2013.

[88] Jared Council, "3D Goes K-12," *Indianapolis Business Journal* 36, no. 19 (July 6, 2015): 3.

[89] Jasmine Kohli, "3D Printing Can Transform Education Sector in India - To Understand How 3D Printing Can Transform the Education Sector in India , Dataquest Spoke to Prasad Rodagi, Founder Director, Altem Technologies," *Dataquest*, June 5, 2015; "MBD Group, the First Publishing House Launches 3D Learning Solutions for K-12 Students," *India Education Diary*, February 14, 2015.

[90] Dataquest, "Indian 3D Printing Startup Creates Educational Tools to Bring Vision to the Visually Impaired," *Dataquest*, June 15, 2015.

laboratories as another example of 3D printing technologies as experimental learning spaces for local innovation systems.

Box 10: Fabrication Laboratories as Experimental Learning Spaces for Local Innovation Systems

3D printing technologies offer significant prospects for developing countries. This technology has the potential to spur innovation, design and tool creation capacity in local societies. This could improve their livelihoods and economic empowerment. In developing countries, however, the deployment of 3D printing is usually limited to universities under specialist research centres such as Fabrication Laboratories (FabLabs).

FabLabs are small-scale workshops equipped to offer digital fabrication for individuals or small-sized companies. They can be found in both developed and developing countries. For instance, Fablab Nairobi is part of the international Fablab network which started at the Massachusetts Institute of Technology (MIT). Nairobi's FabLab, part of the University of Nairobi's Mechanical Engineering Department, was setup to promote local innovation systems in Kenya and introduced 3D printing capabilities in 2012. Some projects that have developed within the lab include a sustainable sanitation solution for slum areas and a "vein finder" device that helps doctors administer intravenous needles to tiny infants. In Tanzania, the innovation think tank Buni Hub is in the process of establishing a FabLab with 3D printers in cooperation with the Finnish government. Their plan is to recycle the tons of e-waste generated annually into developing 3D printers. Another project is to use 3D printers to create teaching aids for primary and secondary schools[91]

Issues for consideration

3D printing can potentially contribute to economic diversification, reduced carbon emissions, and innovative learning in a range of cross-sectoral applications. There are, however, several considerations and challenges that stakeholders and especially policymakers need to consider in order to exploit their potential. The rest of this section discusses some of these issues, namely regulatory frameworks and employment implications.

<u>Create Regulatory Frameworks that address data for 3D Printing</u>

3D printing poses threats with respect to sharing of data, as well as the nature of objects that could be printed. It is unclear whether the free sharing of 3D models on the internet will follow a path similar to that of digital music recently witnessed over the past decade. If so, illegal downloading of 3D models for 3D printing has the potential to negatively impact producers of physical products. As such, governments would need to consider how 3D printing considerations should be part of the cybercrime, data privacy and protection, and intellectual property regulatory frameworks. 3D printed models represent files that can be shared on the internet in ways that breach existing intellectual property regulations or negatively impact whole industries. Such regulatory frameworks must balance private sector

[91] F. Ishengoma A. Mtaho (2014) 3D Printing: Developing countries Perspectives http://inside3dprinting.com/nairobis-fablab-promoting-culture-of-innovation/. Also see: http://www.voanews.com/content/fab-lab-igniting-revolution-in-kenya/1969051.html; http://www.3ders.org/articles/20150116-tanzania-finland-building-fab-lab-using-3d-printers-made-from-local-e-waste.html; http://www.3ders.org/articles/20111212-fablab-nairobistrengthens-kenyas-innovation-system.html; http://buni.or.tz.

innovation and individual creative freedom with national digital threats and crime as well as economic and social implications. If pirated 3D models of common physical products (e.g., furniture) are shared, it could negatively impact the livelihoods of those employed in industries designed to manufacture such objects.

Also, 3D printing technologies could create security threats related to the printing of weapons and uncertainty about how they can be regulated. 3D printed models of firearms pose a credible threat. For instance, in 2014 a court jailed a man who used a 3D printer to make guns in his home and published online videos documenting the process.[92]

Conduct Foresight Exercises on Employment Implications of 3D Printing

3D printing remains a niche technology. At this point, 3D printing is unlikely to displace manufacturing global value chains due to time and cost considerations related to production in the short term, and in the long term its viability to displace traditional manufacturing techniques remains unclear[93]. However, if 3D printing matures to a point where it could disrupt traditional manufacturing, it could potentially negatively affect factory workers in some developed and developing countries with strong manufacturing industries.[94] On the other hand, it could potentially contribute to emerging efforts to engage in local product innovation. As such, foresight exercises could help assess the potential impact of the deployment of 3D printing technologies in labour markets, especially in manufacturing. Such foresight exercises could focus on different industries (e.g., aerospace, consumer electronics, and transportation) and evaluate to what extent 3D printing can substitute or augment such processes.

Possible Scenarios

Table 4: 3D Printing Scenarios

Scenario	Description
(1) 3D printing as Digital Novelty for Hobbyists and tool for tech savvy	3D printing is a toy for hobbyists and "makers" who create specialty craft products. Innovative companies also use it to quickly prototype as well as print complicated parts that are costly to produce in traditional manufacturing processes.
(2) Additive Manufacturing as New Niche in Manufacturing	3D printing does not overtake traditional manufacturing but creates a new niche for low-cost manufacturing of selected products or product categories.
(3) Manufacturing Disrupted	Existing manufacturing global value chains are disrupted as almost any location can set up a 3D printing facility that does competitive manufacturing at a fraction of the cost. The assembly line is re-imagined and whole sets of traditional manufacturing machines are replaced with low-cost 3D printers that have speeds that rival start-of-the-art manufacturing. New industries are created in locations where infrastructure could not previously

[92] "Edge of Technology 3D Printing and Other Amazing Inventions"; "Man Jailed in Japan for Making Guns With a 3D Printer," *Hacker5*, October 20, 2014.
[93] Source: AT Kearney, "3D Printing, A Manufacturing Revolution." Note: mm is millimeters; ppm is parts per million.
[94] Lanier, *Who Owns the Future?*, 2.

	support a manufacturing sector. The building construction industry is reinvented, providing low-cost houses that can be constructed in less than a day.

5. Digital Automation and the Future of Work

Digital automation is characterized by the ability of computers to increasingly take over cognitive tasks - and not just physical - work tasks. The automation of work historically and in contemporary times has had significant implications for government policy on employment, labor markets, and overall economic growth. Countries and businesses that take advantage of digital automation are able to produce products and services at unprecedented scale. Though it increases the productivity of workers and can increase the scale of operations at marginal cost, it can eliminate the need for workers. This section examines digital automation, discusses recent findings on the impact of digital automation on employment, and concludes with several future scenarios of how digital automation could impact employment prospects.

The quote below demonstrates some of the recent advances in automation that will radically reshape our world:

> Digital robots are… in many cases taking on tasks of highly-skilled knowledge workers. We have already seen the extraordinary power of search engines, such as Google Search, Microsoft Bing, and others, based on powerful "ranking" algorithms that far exceed any human capability, almost instantly sifting through billions of data points to answer human information queries. Other powerful algorithms are replacing lawyers with "e-discovery" by scanning millions of legal documents at higher speed, lower cost, and with greater accuracy than humans. Similarly, medical x-rays can now often be read more quickly and more accurately by computers than radiologists. Some digital robots, like IBM's Watson, can help diagnose cancer and will soon provide expert advice across a wide range of medical and other disciplines. Google Translate is constantly improving through massive data mining and advanced algorithms. In short, a large number of jobs and even job categories are or will be eliminated by digital robots.[95]

Recent examples of digital automation are wide-ranging and include the Google Driverless car, robo-journalists from Narrative Science that automatically turn spreadsheet data into custom-written reports, and automated online dating services for match-making.[96] For example, automation enables current information and communication technology for development (ICT4D) projects for transparency and participatory governance in developing countries. For instance, the crowdsourcing software platform Ushahidi (Kenya), that works on election and humanitarian monitoring and has benefited from automation processes applied to the verification of reports submitted by the citizens. Machine learning techniques using natural language processing automatically suggests languages, locations, and categories of incoming reports to help volunteers concentrate on the most urgent cases.[97]

It was previously thought that there was a division between human and digital labor with humans focused on tasks that cannot be reduced to rules or algorithms and computers focused on information processing tasks with well-defined rules.[98] About a decade ago, experts

[95] Atlantic Council, "Envisioning 2030: US Strategy for the Coming Technology Revolution," 20–21.
[96] Cowen, *Average Is over*, 5.
[97] More information is available here: http://dssg.io/2013/07/15/ushahidi-machine-learning-for-human-rights.html
[98] Brynjolfsson, *The Second Machine Age*.

doubted whether machines would be able to drive cars. Similarly, it was argued that computers would not be able to engage in the complex communication tasks of humans as well. In 2015, Google's driverless car has driven millions of miles and a number of technologies engage in complex communication via mobile devices everyday (e.g., Apple Siri, Microsoft Cortana, and Google Voice Search)[99]. Automated translation applications on mobile devices now allow people to converse across language barriers without the need for a translator and at no cost.

Like in the Industrial Revolution, machines are taking on tasks that were previously done by humans. Defining features of recent digital automation are that (1) cognitive and not just physical tasks can be completed by computers; and (2) jobs are destroyed at a faster than they are being created. There are concerns that such developments will inevitably lead to job reductions. 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.[100]

Recent Findings on the Implications of Digital Automation for Employment

Work can be divided into routine vs. non-routine and manual vs. cognitive (see Table 5).Work tasks that are routine - meaning that 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 (e.g. part of assembly line operations) or cognitive (e.g., routine data entry into a computer database). This leads to job polarization where the demand for middle-income jobs, is reduced while the demand for non-routine cognitive jobs (such as financial analysis) and non-routine manual jobs (like hairdressing) may not be affected (see Figure 7)[101]. 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 class 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 resist better automation processes.

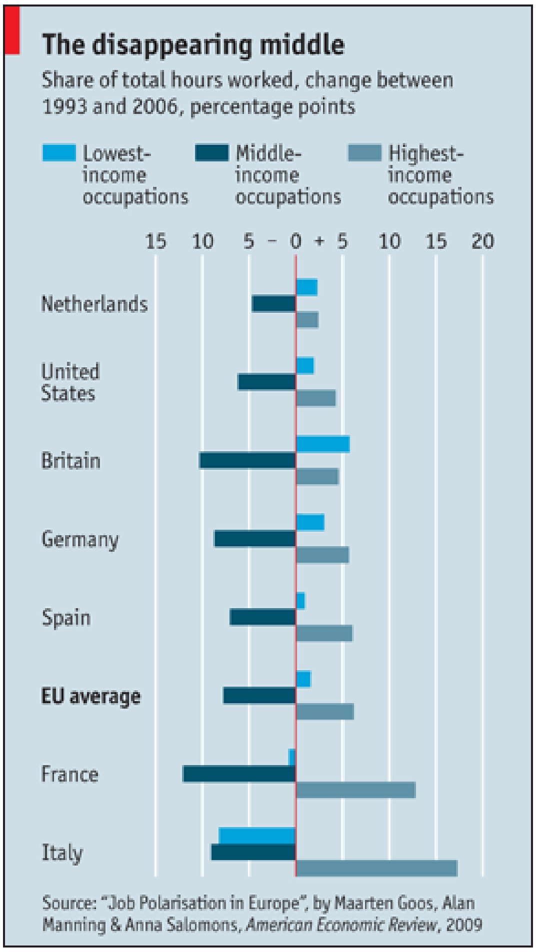
Table 5: Job Polarization Matrix[102]

[99] Brynjolfsson, *The Second Machine Age*, 10–11.
[100] Brynjolfsson, *The Second Machine Age*.
[101] David Autor, "The Polarization of Job Opportunities in the US Labor Market: Implications for Employment and Earnings," *Center for American Progress and The Hamilton Project*, 2010; Daron Acemoglu and David Autor, "Skills, Tasks and Technologies: Implications for Employment and Earnings," *Handbook of Labor Economics* 4 (2011): 1043–1171; Brynjolfsson, *The Second Machine Age*, 139–139; Cowen, *Average Is over*, 37.
[102] David H Autor, Frank Levy, and Richard J Murnane, "Computer-Based Technological Change and Skill Demands: Reconciling the Perspectives of Economists and Sociologists," in *Low-Wage America: How Employers Are Reshaping Opportunity in the Workplace.* (New York: Russell Sage Foundation, 2003), 121–54.

PREDICTIONS OF TASK MODEL FOR THE IMPACT OF COMPUTERIZATION ON FOUR CATEGORIES OF WORKPLACE TASKS

	Routine tasks	Nonroutine tasks
	Analytic and interactive tasks	
Examples	• Record-keeping • Calculation • Repetitive customer service (e.g., bank teller)	• Forming/testing hypotheses • Medical diagnosis • Legal writing • Persuading/selling • Managing others
Computer impact	• Substantial substitution	• Strong complementarities
	Manual tasks	
Examples	• Picking or sorting • Repetitive assembly	• Janitorial services • Truck driving
Computer impact	• Substantial substitution	• Limited opportunities for substitution or complementarity

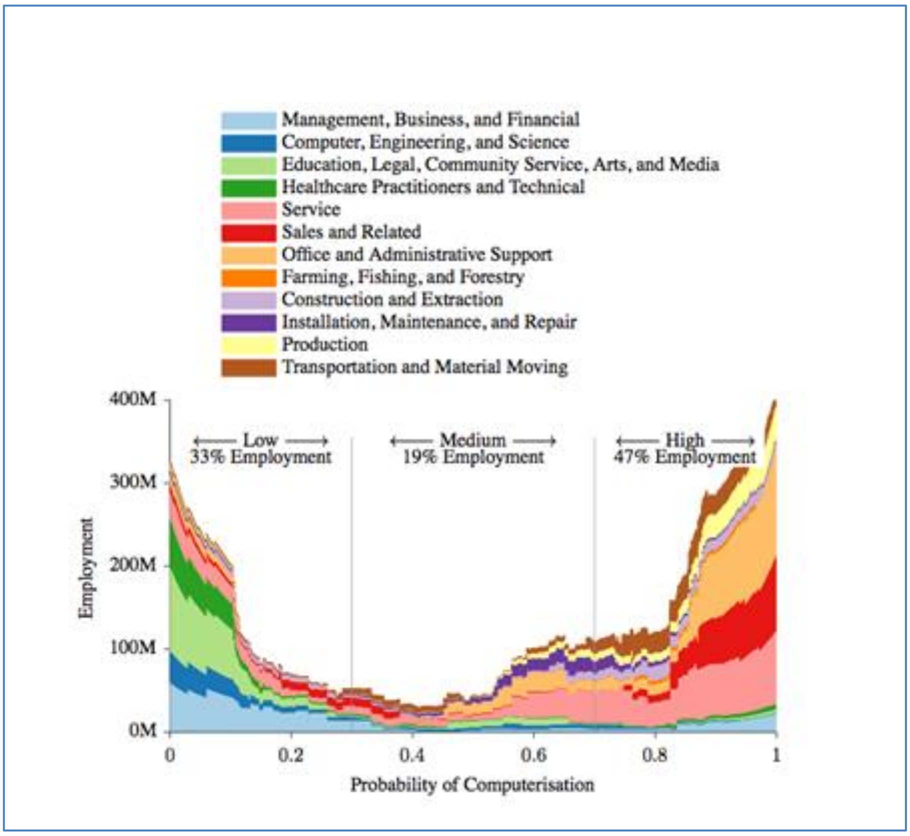
Figure 7: Job Polarization in Europe (1993-2006)



In terms of potential effects of automation, recent research using data from the U.S. has shown that approximately 47 percent total employment in this country is at risk of being computerized (see Figure 8). Specifically, US workers in transportation, logistics, office and administrative support are the most at risk. Additionally, many service workers have jobs highly susceptible to computerization as well.[103] On the other hand, wages and educational attainment are negatively correlated with the probability of computerization. It is predicted that there will be a further hollowing-out of middle income jobs in the US context.[104]

There are important differences between the Industrial Revolution and the current digital age. In the Industrial Revolution, wages and living standards increased alongside productivity. As technology substituted for labor (e.g., agricultural threshing machines replacing 30 percent of labor by mid-nineteenth century) and industrialization continued along, the share of overall GDP to labor remained stable. Machines created as many jobs as were destroyed.[105] For example, the US-based camera company Kodak hired more than 145,000 people at its height of power (and employed more indirectly in retail distribution and supply chain) and was worth $28 billion.

Figure 8: Which Jobs will be Computerized? [106]

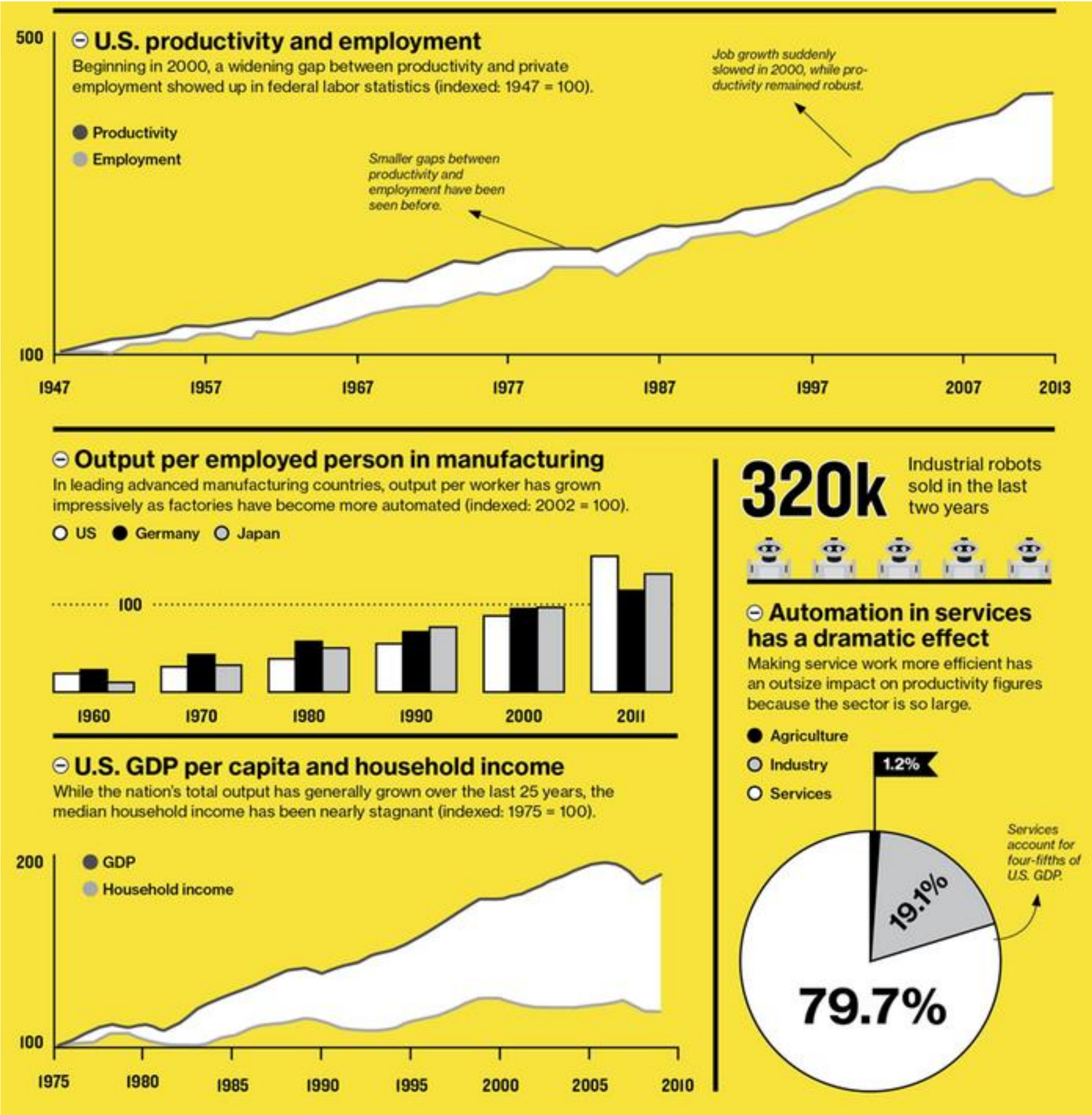


However, there are recent technological developments in which a reduced number of employees creates large amount of wealth. For instance, the online mobile photo-sharing, video-sharing and social networking service Instagram was sold to the social networking company Facebook for one billion dollars in 2012 with only thirteen employees. Those few employees created an application that over 130 million customers used to share some sixteen

[103] Carl Benedikt Frey and Michael A Osborne, "The Future of Employment: How Susceptible Are Jobs to Computerisation" 2013, 44–45.
[104] Ibid., 45.
[105] Cowen, *Average Is over*; Brynjolfsson, *The Second Machine Age*.
[106] Frey and Osborne, "The Future of Employment: How Susceptible Are Jobs to Computerisation."

billion photos at the time[107]. Some technologists argue that the few Instagram employees were able to use network effects to generate value based on the millions of contributions to their application with the effect of centralizing wealth and potentially limiting economic growth.[108] TurboTax - the American tax preparation software package - provides a relatively cheap service at low costs to millions of customers. Tax preparers, a relatively highly skilled group of professionals, have had their incomes and jobs threatened.[109]

Figure 9: Decoupling Productivity and Employment[110]



Several studies have looked into the implications of increasing digital automation for

107 Brynjolfsson, *The Second Machine Age*; Jaron Lanier, *Who Owns the Future?* (New York: Simon & Schuster, 2013).
108 Lanier, *Who Owns the Future?*, 2.
109 Brynjolfsson, *The Second Machine Age*, 10–11.
110 http://www.technologyreview.com/featuredstory/515926/how-technology-is-destroying-jobs/

employment prospects.[111] The reality is that technological advances boost incomes while automation negatively affects the wages of the humans replaced by machines. Though digital tools make it possible to create unprecedented amounts of wealth, there is no theory in economics that guarantees most or all workers will benefit from productivity growth.[112] As a result, unlike the Industrial Revolution, the latest high-tech innovation may not create jobs[113]. For instance, in the case of the US, Figure 9 shows that although productivity and employment in this country have historically kept pace since the middle of the 20th Century, the beginning of the 21st Century shows a divergence between these variables. Productivity growth continues to accelerate as employment growth slows, owing in part to digital automation that is increasingly taking on the tasks of workers. Potentially, this could produce distributive effects as fewer people (i.e., those who own and control productive assets) may benefit from the productivity gains while employment and associated income would be reduced.

Challenges and considerations related to Automation

Many jobs are at risk of being computerized through digital automation. The result could be that increasing productivity is not met with increasing wage and job growth. On the other hand, digital automation can contribute to manage and potentially solve critical challenges at the global, regional, national, and local levels and have cross-sectoral applications. There are, however, several considerations and challenges that stakeholders and especially policymakers need to address in order to exploit its potential as well as mitigate its risks. The rest of this section discusses some of these issues, including building human capacity, creating institutions for monitoring and making transparent such algorithms, and conducting foresight exercises to evaluate the potential employment implications.

Build Human Capacity to address increasing Digital Automation

Public investing in building domestic capabilities may help stakeholders engage in learning processes that shape the future of digital automation instead of simply reacting to it. Governments can actively encourage learning opportunities especially in new industries that may shape job markets[114]. Educational policies can help align the demand and supply for skills through providing training on areas such as general problem-solving and creative skills, which can help their labor force, regardless of technical change.

Create Institutional Capacity for Monitoring and Transparency

Digital automation could potentially affect the lives of many people across the world. Digital automation algorithms using big data enable financial institutions to make decisions regarding credit applications, assist web, internet, and mobile companies in deciding which advertisements to show users, and influence which discounts or deals retailers show potential or repeat customers. The increasing ubiquity of such automation algorithms across economic and social sectors will frame the opportunities individuals are presented and the challenges they might face. Because of the power of such algorithms to increasingly shape the experiences of individuals, new institutional arrangements for monitoring and transparency could be considered.

[111] See for example Lanier, *Who Owns the Future?*, 2.
[112] Brynjolfsson, *The Second Machine Age*, 10–11.
[113] Lanier, *Who Owns the Future?*, 2.
[114] UNCTAD, “Information Economy Report 2012: The Software Industry and Developing Countries,” xiii

The algorithms that feed automated decision making are not infallible and can make mistakes due to communications or sensor failures, unforeseen data volumes, incorrect computer code, or computer or data storage failures.[115] Using algorithms that are not well understood can produce results and shape our world in ways that are not fully understood and potentially reinforce discriminatory biases. New institutions for monitoring digital automation algorithms can work as external entities that audit organizations that use automation technologies and/or internal operations that review data operations. Medicine, accounting, law, and engineering underwent similar transformations and such is needed as automated algorithms become more professionalized and account for more of the services that are used.[116]

Conduct Foresight Exercises on the Employment Implications of Digital Automation

Digital automation could have serious implications for employment prospects. It can be argued that developing countries that rely on low-cost labor as a competitive advantage will be most affected by digital automation in the coming years. If labour can be replaced by robots and other automation, the low wage competitive advantage largely disappears.[117] The automation of manufacturing processes could potentially reduce the impetus to offshore such operations to developing countries. However, developing countries with logistical advantages and strong business ecosystems may be able to resist these changes in the near-term. Similarly, call centres in developing countries are being replaced by interactive voice-response systems (IVRs) and computer transcription. In fact, only tasks that are mature, well-structured, and relatively routine get offshored to developing countries.[118] If these tasks are the easiest to automate, then offshoring may be simply a stop on the way to an automated future that re-shores work back to developed countries[119].[120] Not only business process outsourcing (BPO), manufacturing, and other offshored tasks but agriculture and mining are increasingly being automated.[121].

Countries may consider conducting foresight activities to predict how many people will be displaced by computers and in which sectors (see Box 11). These employment implications should be investigated and feed into national policy planning for economic development, including labour markets, education and skills policies, and industrial policy. If some sectors are particularly affected, policymakers can proactively shape labor market and educational policy to respond to such challenges, in accordance with national development goals.

Box 11: Technology Foresight for Automation and Employment in Singapore

Singapore's Centre for Strategic Foresight along with the Ministry of Manpower recently

[115] [A World Run on Algorithms, p. 7]
[116] Mayer-Schönberger and Cukier, *Big Data*, 6.
[117] At the CSTD Annual Session in Geneva held in May 2015, Kristel Van Der Elst posed the following question, "Will regional competitiveness change if robots cost the same across regions?"
[118] The following World Economic Forum Report also describes "the offshoring path to automation": http://reports.weforum.org/global-strategic-foresight-community/nouriel-roubini-new-york-university-the-third-industrial-revolution/
[119] Brynjolfsson, *The Second Machine Age*, 184–185; Cowen, *Average Is over*, 7–8, 176–177.
[120] The emerging area of Robotic Process Automation (RPA) presents a challenge (and possibly opportunity) for existing business process outsourcing destinations. According to its industry body, "Robotic process automation (RPA) is the application of technology that allows employees in a company to configure computer software or a "robot" to capture and interpret existing applications for processing a transaction, manipulating data, triggering responses and communicating with other digital systems." Source: http://www.irpanetwork.com.
[121] Maha Rafi Atal, "Focus on Private Sector: New Tech Shouldn't Mean No Jobs," *SciDev.Net*, May 29, 2015, http://www.scidev.net/index.cfm?originalUrl=global/technology/analysis-blog/private-sector-tech-jobs-africa-poverty.html.

commissioned a study on how big data, robotics, and artificial intelligence could impact various types of jobs. The initial phase consisted of a quantitative analysis on which jobs had the highest propensity to be automated in the next 20 years while the second phase consisted of qualitative analysis to deepen understanding and verify findings in four occupational clusters (manufacturing, professional services, high-touch service jobs, and low entry barrier jobs). Their more broadly applicable findings suggest that jobs will be transformed (people will increasingly spend more time on tasks requiring creative and social intelligence) and new jobs will be created (new job categories will emerge). Their recommendations for governments were: (1) boosting automation through incentivizing automation (incentivizing firms and promoting ecosystems for automation-related industries); (2) up-skilling citizens for jobs of the future (e.g., focus on STEM skills and skills that are not subject to automation); and (3) addressing the emerging skills divide by providing social and financial support to workers negatively impacted by increasing automation[122].

Possible Scenarios for Digital Automation and the Future of Work

Three scenarios are outlined with respect to the impact of digital automation on the future of work (see Table 6).

Table 6: Digital Automation Scenarios

Scenario	Description
(1) Old Jobs Go, New Jobs Come (Status Quo)	Some jobs disappear, but other jobs replace them as new forms of work and economic activity are created. Fears of robots and automation overtaking human work are unfounded because of the over-estimates of artificial intelligence enthusiasts and the inability of economists and businesspeople to forecast the new economic sectors that will replace the current economic landscape. Technology will continue to automate work processes, but job growth will ultimately keep pace with the technological changes.
(2) Different tasks for humans versus computers	Automation will increasingly encroach on the cognitive tasks performed by humans leading to computers performing much of the repetitive, mature tasks while people focus on ideation, creativity, and judgement. This scenario will lead to some technological unemployment due to the great numbers of people whose work might be substituted by the machine. Workers with complementary skills, as well as technologically-advanced workers who create the automation systems, will have employment security.
(3) Robots Take Jobs	Big data, IoT, and advanced artificial intelligence algorithms will dramatically reduce the number of jobs at a rate greater than the economy can create them. Truck and cab drivers, newspaper journalists, college lecturers, mid-level medical staff, tax preparers, and financial advisors will find themselves out of work. The only jobs that will remain will be that of workers in low-wage service-based occupations (e.g., hairdressers and janitorial workers) or the few, elite computer programmers who create and maintain the automated systems.

[122] Centre for Strategic Foresight. "Foresight", Centre for Strategic Futures, Prime Minister's Office, Singapore, 2015, http://www.csf.gov.sg

6. MOOCs and Digital Learning

Massive open online courses (MOOCs) are online courses that allow for open access and unlimited participation through the World Wide Web. MOOCs potentially provide an opportunity for countries, especially in resource-poor regions, to provide mass education at low cost. This section will briefly introduce the concept of MOOCs, highlight its potential advantages, address some critical considerations about some of its shortcomings, and present a number of scenarios that represent its role in the future of education.

MOOCs do not just involve online video lectures but also typically incorporate social sharing features (e.g., online discussion forum or wiki), interactive quizzes and assignments, supplementary resources (e.g., books, articles, etc.), community teaching assistants who moderate discussion forums and help answer student questions, as well as streaming office hour sessions with professors and staff. The digital nature of the educational content delivery makes it possible to track which videos are watched, what problems students face with assignments, and which issues are most discussed in the online discussion forums.

Potential Advantages of MOOCs

A potential advantage of MOOCs is that they enable low-cost replication of recognized educators, content, and methods.[123] The replication of authoritative content is something that started with the integration of the textbook into the traditional classroom setting. MOOCs allow educational standardization for students worldwide. This means students potentially could read the same literature, work on the same arithmetic problems, and learn the same history (Khan, 2013: 72-74). Second, self-paced learning gives students the ability to control the *tempo* of learning. Furthermore, the lessons and lectures are always available, offering a significant advantage. This facilitates the review of former lessons as well as helping to make connections between lessons in different subjects.[124] Third, MOOCs help teachers collect a huge volume of data analytics on learning offered through the platforms. With the enormous stream of data from courses, including which students click on course material, the thousands of comments on class discussion boards, the homework and exam assessments, the times course materials were accessed, the demographic profile of students, and other factors, educators can understand more about how students learned in their classes. Fourth, though no systematic study has yet been conducted on the gender implications of MOOCs, some tentatively claim that it has the potential to be beneficial for women in education.

Considerations on the deployments of MOOCs

As discussed in this section, 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 scaling up education and making high quality educational content to the underserved, respectively. However, there are specific policy and regulatory issues that need to be considered to take advantage of the benefits of the MOOCs while minimizing risks and disadvantages. Some of these include the creation of local content, evaluating employment implications, experimenting with MOOCs, bridging the digital and education divides, and safeguarding data privacy and security.

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[123] Brynjolfsson, *The Second Machine Age*, 210.
[124] Salman Khan, *The One World Schoolhouse: Education Reimagined*, Reprint edition (New York: Twelve, 2013), 56–58.

Encourage the Creation of Local Educational Content through MOOCs

The content provided by MOOCs may not be relevant for local context. For instance, most MOOCs are available predominantly in English, and as a result significant proportions of students might get excluded from the benefits of MOOCs. This raises the importance of multilingualism on the Internet and the creation of local content. Further, the examples and illustrations used in many MOOCs might be from developed country settings, which might be difficult for a developing country student to relate to. This could further reduce the effectiveness of courses delivered through MOOCs.

As part of current efforts to create local content, educational institutions, private sector entities, and government departments at the national, regional, and local levels can create educational content (see Box 12). The creation of educational content not only serves students but can also become a mechanism for building a culture of digital literacy among content creators, whether they are teachers in primary or secondary schools, professors in vocational or tertiary institutions, policy makers in government, training personnel within companies, or program managers and experts within non-profit organizations.

Box 12: Education providers in India and Africa creating local content and adapting existing content for local contexts[125,126]

In Rwanda, Kigali-based Kepler is a nonprofit university programme that combines online learning with in-person seminars. The cost of education is reduced with the pairing of students with online content and local teachers. The initial degree programmes are in Communications with a focus on Business, Health Care Management, and Management. Other programmes develop content on global MOOC platforms with a specific goal of creating local content for the region. For example, the Indian Institute of Management (IIM)-Bangalore launched over 4 MOOCs on edX, the non-profit online initiative by MIT and Harvard, since 2014. The content is available in English and Hindi with eventual plans to incorporate Kannada, Bengali, and Tamil.

Deployment of MOOCs and the impact on teachers' jobs

There is concern that MOOCs will replace the vast majority of teachers with internet-based content. It has been claimed that well-intentioned MOOCs could potentially undermine the finances and professional security of academics. College students at non-elite schools may use the MOOC content provided online by elite universities and question the usefulness of their local teaching and professorial staff. Relying on a few superstar academics to teach particular subjects can lead to massive inequalities, where a few schools have good teachers, researchers, and classroom interaction and the rest of universities and colleges get videos. Thus, the MOOC revolution may benefit a few elite professors at the expense of teachers in traditional classroom settings.[127]

Consider Experimenting with MOOCs and other forms of ICT-enabled learning

[125] www.kepler.org
[126] The Times of India - Bangalore Edition, "IIMB will launch free online courses in July", 12 June 2015
[127] Lanier, *Who Owns the Future?*, 94–96.

Digital learning technologies, such as MOOC's, do not guarantee improved educational outcomes and only through experimentation, monitoring, and evaluation can its impact be assessed. Policymakers and stakeholders within education departments may experiment with these new platforms to see how they best serve communities, especially those without access to traditional or formal education. Such experiments might require new investments in ICT infrastructure, training for digital literacy, and rethinking the organizational and institutional contexts in which learning takes place. However, the results can inform future choices regarding pedagogical and technological innovation in education and address local and regional educational goals.

MOOCs and potential education and digital divides

MOOCs provide an opportunity for democratizing higher education and reaching the low and medium income countries through online courses (free of charge or at low cost) accessible to people all over the world, contributing to reduce inequalities. In addition, MOOCs introduce more flexibility in learning practices which facilitates participation of different segments of the population as well as people from rural areas (OECD, 2005[128]).

However, there are a variety of factors that limit access to MOOCs, and digital divide is one of them. For instance, participation in a MOOC requires users to have an internet connection to access the courses, upgraded software and hardware, which means that students from less interconnected regions as well as rural areas -with no internet and/or electricity infrastructure- would not benefit from MOOCs. Further, even though MOOCs can help people deepen their skills or acquire new ones most MOOCs do not grant degrees and as a result may not have an effect on upgrading the abilities of workers in the labour market so they can find a job.

Also, people may not have the knowledge and skills required to engage with MOOCs. Studies show that the majority of MOOC students are actually already educated. In one study, between 70 and 80 percent of MOOCs students registered already had college degrees. For MOOCs students currently residing in developing countries such as China, Brazil, Russia, India, and South Africa, 80 percent of them had a college education (compared to 5 percent of residents in many of these developing countries)[129]. Given that most people who use MOOCs are overwhelmingly educated and middle-class, their access to such tools can widen the skills gap between them and those without access to internet connectivity and education. This indicates that even though MOOCs have the potential to bridge learning divides it can also create new divides.

If governments are interested in developing or supporting ICT-enabled learning projects, including MOOCs, it must tackle the existing economic, social, digital, and educational divides so that underserved and marginalized communities benefit.

Safeguard Privacy and Security of Online Education Data

Data privacy and security must also be safeguarded, especially for youth who use such platforms. ICT-enabled learning, including MOOCs, generates massive amounts of data and such platforms may involve the collection of demographic, family, and personal data. Care has to be taken in ensuring that the data collected is not indiscriminately shared outside of its original educational intent. If private sector stakeholders are involved in accessing, storing,

[128] OECD Skills outlook 2015: Youth, Skills and Employability, OECD Publishing
[129] Derek Newton, "The (Accidental) Power of MOOCs."

and analyzing such data, appropriate frameworks for data protection, sharing (with students and education system), and confidentiality must be created. Governments can also propose the creation of personal information acts that specifically guard the online privacy rights of students who use such e-Learning platforms.

Scenarios for MOOCs

Two scenarios are outlined below addressing the potential role MOOCs can play in education policy (see Table 7).

Table 7: MOOCs Scenarios

Scenario	Description
(1) Promote ICTs generally as supplements to existing educational policy	Videos are a supplemental resource used to enhance learning in existing educational contexts. Educational videos can be suggested by teachers or engaged by self-initiated students. Online courses and material deepen subject matter but do not change how course material is disseminated or tested in the classroom.
(2) Experiment with MOOCs as part of educational policy	Policymakers may experiment with the use of MOOCs in classroom settings. In the case of flipped classrooms, the students may receive lectures at home and have interactive problem sessions at school. The teacher serves primarily as a mentor and a coach. Such educational experiments can be tested with randomized controlled trials and inform education policy reform.

7. Broad Policy Considerations for Future Digital Developments

This final section provides broad policy considerations to address the digital developments covered in this paper so as to maximize their development potential and minimize the risks that come along with them.

Emerging digital developments can be harnessed as significant drivers of sustainable development

The digital developments examined here can be embedded within and catalyze national plans for sustainable development. Understanding the cross-cutting role of such digital developments can help stakeholders within government, the private sector, civil society, and the international community to explore how such technologies might affect development policy and contribute to meeting the sustainable development goals. Stocktaking exercises can be carried out that analyze how such technologies can promote existing sectoral policies and strategies (e.g., health, agriculture, energy, water, sanitation, etc.).

In particular, Big data and IoT can assist in the monitoring mechanisms needed to follow-up progress in achieving national development goals, including those related to SDGs, and can provide opportunities to diversify into new economic activities as well as strengthen existing ones. Further, a number of the technologies presented in this paper have implications for environmental sustainability. For instance, 3D printing could help reduce the carbon emissions associated with production processes as well as the need for transporting some goods. MOOCs can help deliver educational content without an extensive physical footprint. Digital automation in manufacturing processes can reduce energy expenditures, and big data and the Internet of things can be used to monitor and manage energy utilization as well as carbon emissions. However, these potential impacts require government leadership to ensure that sustainability is a priority application for these digital developments.

One way to support the application of these digital developments to the pursuit of national development goals is through government-led efforts. For example, in regions where the private sector is small or weak, big data projects might be initiated by government as a proof of concept in creating new products or processes. Governments might also consider relying on local software developers and designers to create applications that harness local data for citizen-to-government and government-to-government applications. These initiatives could be used to especially involve millennials in the achievement of the sustainable development goals in a local or national context.

Internet of Things applications could be mainstreamed within national agricultural development plans and strategies to provide up-to-date information on agricultural yields for effective decision-making. Pilot 3D printing programs can be explored for the production processes of goods or products produced specifically for or promoted by government. Digital automation might be deployed in e-government services to make the public sector more responsive to the needs of citizens. Such projects might create a set of pilot experiences and human capital that could be deployed elsewhere across the public and private sectors.

Emerging digital developments may create new digital risks and digital divides

Despite the potential benefits of the emerging digital technologies discussed, they also raise potential risks, which should be considered and appropriately managed. There is a need to create more awareness about cybercrime and to develop cybersecurity policies and strategies. For example, there is a need to safeguard against the illegal sharing of data for 3D printing as well as the unauthorized use of private or confidential data from web applications, eLearning and MOOC platforms, mobile phones, and IoT devices. Such regulatory policies on data should seek to balance individual and collective rights (including freedom of expression and information) while safeguarding privacy and security and ensuring that private sector players can innovate. With respect to the Internet of Things, frameworks for the interoperability of IoT devices should be formulated. Beyond formal regulatory interventions to safeguard against data threats, new institutional mechanisms for monitoring the use and sharing of data as well as evaluating the societal implications of how algorithms are applied in the real-world can be created and supported by government. Governments can also work with local private sector partners to promote company-level practices for safeguarding privacy and security that are compatible with national regulation.

The digital developments discussed in this paper may create opportunities to develop new tools to promote sustainable development, but they can also exacerbate existing economic, social, and technological divides. Big Data and the Internet of Things are powerful digital technologies that have the potential to transform virtually every economic sector. However, it is possible that such technologies will be harnessed by countries, regions, and cities with strong existing capabilities to make use of digital developments, leaving others further behind. For instance, 3D printing could provide a new opportunity for countries, regions, and cities to leapfrog into manufacturing but much of the innovations in 3D printing emanate from countries that already have well-established manufacturing capabilities. 3D printing could potentially augment the strengths of global leaders rather than help others catch up. Similarly, MOOCs may enable middle-class, digitally-connected, relatively well-educated students and professionals supplement their education with world-class content, leaving those without digital access, economic opportunity, or accessible education behind.

Public-private partnerships and international cooperation can strengthen local innovative capabilities for digital developments

Public-private partnerships and international cooperation can be effective mechanisms for the building of capabilities in big data, the Internet of Things, 3D printing, MOOCs, and digital automation technologies. Overseas development and multilateral assistance programs can have a "knowledge aid" component that assists developing countries in their data collection efforts while strengthening their human capabilities to collect, store, analyze, visualize, and communicate data. Alternatively, targeted assistance for agriculture, fisheries, environment, and transport infrastructure could include funds for IoT devices as well as training on deployment, data analysis, training, and automation. Furthermore, big data held by both domestic and multinational companies could be shared with the public sector as part of public-private partnerships for public, social, and development initiatives.

Such partnerships can facilitate or enhance the sharing of data that is put to the service of sustainable development. Though data privacy and security issues should be taken into account, such partnerships and collaborative efforts can strengthen ongoing efforts to deepen human capacity to harness the benefits of such technologies while limiting their risks. North-South and South-South partnerships can be harnessed to share best practices for applying MOOCs, Big Data, IoT, Digital Automation, and 3D printing to local circumstances, problems, and applications. And international partnerships can also be used to facilitate technology foresight on these digital developments and their potential applications.

Technology foresight activities can help countries develop science, technology, and innovation (STI) policies

Countries might consider engaging in foresight exercises to understand the role digital developments will play in their own national context and how they might affect the economy, society, and the environment. The impact of such foresight initiatives can inform science, technology, and innovation policies, shape funding and implementation strategies, and backstop planning and decision-making processes across various sectors of the economy.

Developing the institutional capacity to understand how new technologies, and especially digital developments, will impact the economy, society, and environment is extremely important and can be applied to future scenarios and technology developments. Developing foresight capacity allows countries to proactively consider the role of technologies and their likely impact on significant sectors of the economy and society. Understanding all the possible scenarios that emanate from the advent of a new technology can help policymakers develop policies, plans, and roadmaps robust to the different outcomes that new digital developments may potentially create. Relevant lessons emerging from such foresight exercises could be shared through global platforms such as the CSTD.

Even if countries do not adopt a particular digital technology in a local or national context, it is important to understand how it could impact the economy. For example, some of these digital developments have and will continue to shape the productivity of certain companies, industries, and perhaps regions across the world, having implications on the global economy.

Such technological developments taking place in other parts of the world can exert shocks across countries, creating economic, social, and/or environmental impacts.

Harnessing digital technologies for development requires investments in human capital

Virtually every digital development in this paper requires appropriate local talent to harness its benefits as well as evaluate its implications for economy, society, and environment. Hence, there is a need for regular country and sector specific skills gap analyses to inform policy makers. For example, the United Nations Statistical Commission conducted a survey among national statistical agencies worldwide on the use of Big Data within national statistical agencies and the survey identified the lack of necessary set of skills and expertise as a major challenge. [130] This was found to be true even in countries like Kenya, which is considered a leader in ICT adoption in Africa[131]. Education and skills development systems need to become more flexible in order to quickly respond to the results of such gap analyses. General literacy, ICT, and data literacy skills at all levels should be encouraged in addition to the promotion of creativity, problem-solving, and STEM-related skills. Tertiary institutions and technical and vocational schools can create new courses, programs, certificates and degrees that incorporate elements of big data analysis, the Internet of Things, MOOCs (and learning analytics), and automation (esp. artificial intelligence). Firms may need to invest in rapidly upskilling their workers to take advantage of new technologies. Governments may promote an understanding of these technologies by policymakers.

Free and Open Source Digital Technologies provide opportunities for local, inclusive, pro-poor innovation

Many of the emerging digital technologies presented in this paper are free and open source, potentially providing a platform for local innovation. A multitude of artificial intelligence and machine learning algorithms, big data technologies, and MOOC platforms (and content) are built on technology with open access licenses making them freely available for use, sharing, modification, and adaptation. Governments could explore making shareable 3D printers available in local innovation labs or science parks so that new entrepreneurs can easily prototype their ideas. This would create opportunities for local innovation adapted to local needs and markets. Governments may also consider using and adapting existing MOOC platforms as part of national eLearning initiatives to provide locally relevant educational content at scale and in local languages. Local colleges and universities can develop adaptations of open source machine learning and statistical algorithms, targeting them for domestic challenges involving health or agriculture. One of the reasons such digital developments are so interesting is that countries, and particularly developing countries, could contribute to shape the evolution of these technologies through local development. However, even though there are few proprietary bottlenecks to the acquisition of such technologies, required talent is needed to work with and innovate using these technologies.

New digital developments require digital infrastructure and an enabling environment

Strong investment in ICTs has enabled developed countries to establish near-ubiquity broadband access while also driving continued upgrades in the quality and speed of networks available to both businesses and citizens. Although most developing regions are also

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[130] file:///P:/My%20Documents/Intersessional%202015/Foresight%20for%20Digital/2014-11-BigData-E.pdf
[131] http://www.scidev.net/global/data/feature/obstacles-big-data-development.html

experiencing significant investment in ICTs, broadband access remains limited in developing countries[132]. This underlines the importance of investment to developing countries' capacity to fully engage and take advantage of these emerging ICTs technologies. This is not simply a matter of network availability, but also of the reliability, security, quality and cost-effectiveness of networks in order to ensure stakeholders that the networks and services on which they depend would be continuously operational and that data transmitted would be protected. In this regard, policy makers may benefit from monitoring their digital ecosystem, identifying their infrastructure needs, and aligning their investment plans accordingly. Additionally, countries may consider creating the necessary incentives to promote private investments towards needed infrastructure components.

8. Questions for Discussion

Technology Foresight

- Is your country actively using technology foresight as a tool for development planning?
- Which forecasting methodology is most appropriate for your country?
- Which technologies are most relevant for your national development goals?
- Do you know of specific think tanks, consultancies, or related organizations that can assist your country or region with foresight activities?
- What are the opportunities for your country or region to not only respond to but actively shape specific digital developments?

Big Data and the Internet of Things

- How much data is being generated in your country or city through web and mobile applications, Internet of Things devices, and the digital exhaust of computing and related devices?
- In what ways can IoT devices contribute to healthcare, manufacturing, transportation, buildings, retail environments, smart cities, and homes?
- Is there a particular niche of Big Data and IoT that your country is ripe to exploit over the next 10-15 years?
- Are domestic cloud computing providers available to help exploit the power of Big Data and IoT? Or would your country rely on global, corporate providers for access to computing and storage resources in the cloud?
- How can local colleges, universities, and technical and vocational institutions support the development of talent in big data and IoT?

MOOCs

- To what extent can MOOCs help your country reach more students?
- Are local colleges and universities already developing online educational materials? If so, what are the current results and impacts?
- Are there plans under discussion to flip the classroom or integrate more online material into classrooms?
- Does local digital infrastructure support the delivery of education in an online format, especially for the disadvantaged?

[132] UNCTAD, "Implementing WSIS Outcomes: A Ten-Year Review" (New York and Geneva: United Nations, 2015) .

3D Printing

- How will 3D printing shape end-to-end value chains in sectors in your country?
- How robust are domestic companies' value chain strategies against 3D printing disruptions?
- What are the most relevant 3D printing disruption scenarios?
- What are the opportunities for leveraging 3D printing across sectors?
- How can 3D printing be integrated into primary, secondary, and tertiary education?

Digital Automation

- To what extent can your country benefit from automation? In which particular sectors?
- Do you think that the increasing automation will destroy jobs or create jobs?
- To what extent is work becoming more or less labour intensive?
- What types of jobs in your domestic economy will likely be automated? Which types of jobs will not likely be automated?
- Is your country engaging in foresight activities on employment and the future of work?