POLICY APPROACHES TO DIRECT FRONTIER TECHNOLOGIES TOWARDS INCLUSIVE AND SUSTAINABLE DEVELOPMENT
The Economic and Social Commission for Asia and the Pacific (ESCAP) serves as the United Nations’ regional hub promoting cooperation among countries to achieve inclusive and sustainable development. The largest regional intergovernmental platform with 53 member States and 9 associate members, ESCAP has emerged as a strong regional think-tank offering countries sound analytical products that shed insight into the evolving economic, social and environmental dynamics of the region. The Commission’s strategic focus is to deliver on the 2030 Agenda for Sustainable Development, which it does by reinforcing and deepening regional cooperation and integration to advance connectivity, financial cooperation and market integration. ESCAP’s research and analysis coupled with its policy advisory services, capacity building and technical assistance to governments aims to support countries’ sustainable and inclusive development ambitions.
POLICY APPROACHES TO DIRECT FRONTIER TECHNOLOGIES TOWARDS INCLUSIVE AND SUSTAINABLE DEVELOPMENT

December 2021
Executive summary

During the COVID-19 pandemic, digital frontier technologies, such as artificial intelligence (AI) and big data analytics, amongst others, were mobilized to fight against the pandemic. To build back better from the pandemic and meet the ambitions of the 2030 Agenda for Sustainable Development, it is imperative to ensure that these technologies are also directed towards inclusive and sustainable development objectives.

Indeed, digital frontier technologies offer a multitude of opportunities to re-imagine how our economies could serve economic, social and environmental needs. Technologies and innovation are central to long-term economic growth; the adoption of technologies and innovation in production processes increases overall productivity and expands production possibilities. Governments have been using digital technologies to reduce social inequalities and support inclusion. As an example, the Aadhaar technology has enabled the financial inclusion of 1.2 billion people in India. Finally, some countries in Asia and the Pacific have promoted the adoption of state-of-the-art technologies to address environmental impacts. For instance, in the Republic of Korea, the entire smart city of Songdo is built around the Internet of Things (IoT).

Despite such wide-ranging opportunities, the use of digital frontier technologies poses challenges as well. First, the impact of such technologies on the availability of future jobs is uncertain. Second, despite the rapid penetration of the Internet, several billion have been left behind in terms of access to digital technology. As ICT infrastructure is the backbone of digital frontier technologies, there is a risk of it triggering a new digital divide, and compounding an already existing one. Third, digital frontier technologies pose questions about trust and ethics.

In this context, this report reviews the status of digital frontier technologies in the Asia-Pacific region. The report stresses that the impacts of a technologically driven future are far from pre-ordained. Therefore, digital frontier technological breakthroughs require us to think differently about how we have traditionally formulated policies in the use of technology. The policy framework for the next generation of technologies should focus on creating an enabling environment for digital frontier technologies to positively impact the economy, the society, and the environment, and to reduce inequalities. A few pre-requisites for the development and application of digital frontier technologies are:

1) Inclusive ICT infrastructure;
2) Developing a workforce fit for a Fourth Industrial Revolution future;
3) Developing innovative regulatory frameworks;
4) Incentivizing responsible frontier technology development in the private sector;
5) Catalysing the role of the government in the evolution of frontier technologies;
6) Creating a platform for multi-stakeholder and regional cooperation; and
7) Making digital frontier technologies serve the poor people and the least developed countries.

Cross-government cooperation, inter-governmental knowledge sharing and consensus building, and honest, open and regular discussions with the civil society and the private sector, specifically technology developers, will be critical to ensure that digital frontier technologies have a positive impact for inclusive and sustainable development.
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<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
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<tr>
<td>ASEAN</td>
<td>Association of Southeast Asian Nations</td>
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<td>CSR</td>
<td>Corporate social responsibility</td>
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<td>DESA</td>
<td>United Nations Department of Economic and Social Affairs</td>
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<td>ESCAP</td>
<td>Economic and Social Commission for Asia and the Pacific</td>
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<td>GDP</td>
<td>Gross domestic product</td>
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<td>GPT</td>
<td>General-purpose technologies</td>
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<td>ICT</td>
<td>Information and communications technology</td>
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<td>IT</td>
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<td>IoT</td>
<td>Internet of Things</td>
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<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
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<td>R&amp;D</td>
<td>Research and Development</td>
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<td>SDG</td>
<td>Sustainable Development Goal</td>
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<td>SME</td>
<td>Small and Medium-sized Enterprise</td>
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<tr>
<td>STI</td>
<td>Science, Technology and Innovation</td>
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<tr>
<td>TFP</td>
<td>Total Factor Productivity</td>
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<tr>
<td>UNCTAD</td>
<td>United Nations Conference on Trade and Development</td>
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<td>UNESCO</td>
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1. Introduction
1. Introduction

1.1 Classifying frontier technologies including digital frontier technologies

There is no universally agreed definition of what comprises frontier technology. However, a recurring, common feature across the different technological advances is that they all “have the potential to disrupt the status quo, alter the way people live and work, rearrange value pools, and lead to entirely new products and services” (Manyika and others, 2013).

Many frontier technologies can be classified as general-purpose technologies (GPTs). While technological progress is often an incremental innovation in a specific sector or area, GPTs have the potential to re-shape the economy and boost productivity across all sectors and industries. Steam, electricity, internal combustion, and information technology (IT) are just a few examples of GPTs. More generally, it has been argued that GPTs have the following three characteristics (Bresnahan and Trajtenberg, 1995):

1. Pervasiveness – GPTs should spread to most sectors.
2. Improvement – GPTs should become more efficient and effective over time and keep lowering costs for users.
3. Innovation spawning – GPTs should enable the invention and development of new products or processes.

What is deemed to be “frontier” depends on context. Although some frontier technologies are “new”, in other cases they may be a different application or a bundling of more established technologies (Institute of Development Studies, 2016).
For these reasons, a multitude of different technologies have been identified as “frontier”. For example, the Organisation for Economic Co-operation and Development (OECD) listed 40 frontier technologies (Figure 1) and mapped them into four quadrants that represent broad technological areas: biotechnologies, advanced materials, digital technologies, and energy and environmental technologies (OECD, 2016a). In this chart, technologies are mapped closer to or further from the boundaries of other technologies to reflect their relative proximity or distance. Furthermore, in the area of digital technologies, OECD singled out the following four technologies which may have more significant impacts than others: artificial intelligence (AI); big data analytics; blockchain; and the Internet of Things (IoT).

**Figure 1. The 40 key emerging technologies for the future**

Source: OECD, 2016a.
While the technologies may be different and have unique functionalities, they are often inextricably linked with increasingly blurred boundaries. Figure 2 shows that frontier technologies, such as advanced sensors, IoT, AI, drones, blockchain, biotechnologies, autonomous vehicles, and robots, can be utilized to address the challenges related to the sustainability of oceans.

**Figure 2. Frontier technologies can be a game-changer for oceans**


### 1.2 Key digital frontier technologies

The Asia-Pacific region leads in the development of digital frontier technologies and is forecast to be a prominent market in the future. This section highlights a few selected digital frontier technologies which, as mentioned earlier, have been selected by the OECD as being most important.
1. Introduction

Artificial intelligence (AI)

The term AI has been used since the 1950s. It generally refers to computer systems that can perform tasks that normally require human intelligence. In most cases, AI should be regarded as narrow AI (or weak AI), in that it is designed to perform a narrow task (e.g., playing chess, facial recognition, Internet searches, or driving a car). General AI (strong AI) that has cognitive capacity, like humans have, is not available although there are debates as to whether or how soon general AI will outperform humans in the future.

Box 1. Creativity and unpredictability of artificial intelligence

Underlying AI technology is deep learning that has proven to be very powerful at solving problems in recent years, and it has been widely deployed for tasks like image captioning, voice recognition, and language translation. For example, Siemens has been using AI and the IoT to find ways to reduce emissions from gas turbines. AI shows the capacity to find new ways to run the turbines. “Our engineers do it from their experience, their domain know-how. AI does it in a different way”, says Roland Busch, Siemens’ Chief Technology Officer. “Sometimes the system itself comes to a solution which you had never thought about. It’s a little bit scary”.a

On the other hand, deep learning can be a double-edged sword. Its algorithm can be difficult to understand even by its creators, and therefore, the decision it makes may be very unpredictable. An MIT Technology review comprehensively reviewed the risks related to deep learning and proposed the question, “How well can we get along with machines that are unpredictable and inscrutable?”b

Data on the level of investment of AI in the region is limited. According to McKinsey, corporations invested between $20 billion and $30 billion globally in 2016. Large technology companies, such as Alibaba, Amazon, Baidu, Facebook and Google, account for more than three quarters of total AI investment to date. From 2011 through to February 2017, these companies were behind 29 of 55 major merger and acquisition deals in the United States of America, and 9 of 10 major deals in China (Chitturu and others, 2017).

Estimates suggest that China’s total investment in AI enterprises reached $2.6 billion in 2016 (Bajpai, 2017). Singapore recently announced plans to invest over $100 million in AI over the next five years (Choudhury, 2017). In the Republic of Korea, SK Telecom announced, in early 2017, that it would invest $4.2 billion in AI (Colquhoun, 2017).

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4 | Studies in Trade, Investment and Innovation No. 95
Measured by the number of patents filed, from 2010-2014, the United States has been leading AI-related patent applications submitting 15,317 applications. China was second, submitting 8,410. During this period, Japan and the Republic of Korea submitted 2,071 and 1,533, respectively. India was also among the top 10 countries globally in terms of numbers of patents submitted. In addition, China and India are among the top 10 countries in terms of the number of AI companies (Nikkei Asia, 2017; The Economist, 2017a).

**The Internet of Things (IoT)**

Internet of Things represents a concept in which network devices can collect and sense data, and then share that data across the Internet where that data can be utilized and processed for various purposes.

The term, Internet of Things, goes beyond devices traditionally connected to the Internet, such as laptops and smartphones, and includes all kinds of objects and sensors that permeate the public space, the workplace and homes, and that gather and exchange data with one another and with humans. IoT is closely related to big data analytics and cloud computing. While IoT collects data and acts based on specific rules, cloud computing offers the capacity for the data to be stored, and big data analytics empowers data processing and decision-making. In combination, these technologies can empower intelligent systems and autonomous machines.

IoT is spreading rapidly, however, estimation of the market size varies substantially from each other. For example, McKinsey estimates that IoT will add around $11 trillion of market value globally by 2025, roughly divided equally between high-income and developing economies (McKinsey Global Institute, 2015). Another estimation shows that the global market for the IoT technologies is estimated to grow from $370.5 billion, in 2021, to reach $1.3 trillion by 2026, at a compound annual growth rate (CAGR) of 27.6 per cent during the forecast period of 2021-2026 (BCC Publishing, 2021). According to a report published by the Boston Consulting Group, by 2020, companies will be spending an estimated €250 billion a year on IoT, with half of the spending coming from the manufacturing, transport and utility industries (Hunke and others, 2017). Ericsson notes that there are already 230 million cellular Machine-to-Machine subscriptions for IoT applications, and it projects up to 26 billion connected devices by 2020 (Ericsson, 2015).

**Blockchain**

Blockchain is a relatively young technology (especially compared with AI). Blockchain technology was invented to create Bitcoin. It was introduced to the world in 2008, in a White Paper titled “Bitcoin: A Peer-to-Peer Electronic Cash System”, and published under the pseudonym Satoshi Nakamoto, whose true identity has never been revealed (UNCTAD, 2021a).
While the Bitcoin network only records transactions of cryptocurrency, second-generation blockchains (Blockchain 2.0) expand it by allowing the record of computer code in the ledger. It is like creating a distributed hard drive that stores computer code that can be executed in the nodes of the network. Thus, for instance, instead of only registering that a payment has been made, the blockchain can store “smart contracts” that are executed automatically when their conditions are met. The incorporation of smart contracts enables business functions involving the transfer of information and value, while leaving transparent and reliably auditable information trails (UN/CEFACT, 2020).

The latest technological advances in blockchain are clustered around what could be called Blockchain 3.0, which focus on addressing the drawbacks of the previous two generations of blockchain technology, such as scalability and interoperability between different blockchains (Ackermann and Meier, 2018). For example, blockchain can potentially support supply chain and trade across manufacturing, food, pharmaceutical, health and creative industries through integrating varied systems, managing commercial transactions and fostering the traceability of assets (Box 2).

Box 2. Blockchain for international trade

Blockchain technology has been gradually applied to international trade and supply chain management. A.P. Moller–Maersk and IBM jointly created TradeLens which applies blockchain to the world’s global supply chain. TradeLens is a blockchain-enabled shipping solution designed to promote more efficient and secure global trade, bringing together various parties to support information sharing and transparency, and spur industry-wide innovation. Since 2019, TradeLens has been used by 175 organizations.a

The Global Shipping Business Network (GSBN) is a blockchain shipping network that aims to digitize trade, boasts three top-10 container shippers and four port terminal operators, most of them in Asia. The founding shareholders are COSCO SHIPPING LINES, COSCO SHIPPING PORTS, Hapag-Lloyd, Hutchison Ports, OOCL (COSCO owned), SPG Qingdao Port, PSA International and Shanghai International Port Group.b


According to the United Nations Conference on Trade and Development (UNCTAD), top providers of blockchain (blockchain-as-a-service providers) service include Alibaba, Amazon, IBM, Microsoft, Oracle and SAP (Germany) (UNCTAD, 2021b). Top users of blockchain as measured by spending on blockchain services were the finance, manufacturing and retail sectors.
Big data analytics

The term “big data” refers to the massive size of information that contrasts markedly with data arising from traditional sources like structured surveys, administrative records or experiments, whose datasets usually contain a few thousand points, at most. Indeed, the big data revolution consists of more than just size: it refers to data generated by the spontaneous interaction with interconnected devices. It is this spontaneous nature that is behind the massive size, and what separates big data from other traditional sources of information (Escudero, 2020).

Data is claimed to be the new oil. Smartphones and the Internet generate a large amount of data; virtually every activity creates a digital trace, and more raw material for the data distilleries. As devices from watches to cars connect to the Internet, the volume of data increases: some estimate that a self-driving car will generate 100 gigabytes per second. Algorithms can predict when a customer is ready to buy something, when a jet-engine needs servicing or when a person is at risk of a disease. Technology giants have always benefited from network effects: the more users Facebook signs up, the more attractive signing up becomes for others. With data there are extra network effects. By collecting more data, a firm has more scope to improve its products, which attracts more users, generating even more data, and so on (The Economist, 2017b).

Big data analysis is often associated with AI and IoT. Indeed, big data analysis and AI mutually reinforce each other: to make AI work, big data are required to feed machine learning. Meanwhile, AI techniques, such as machine learning, extract useful information from often unstructured data. Similarly, big data analysis is essential for IoT. Without big data analytical work, there will be an ocean of data generated by IoT but only drops of information.

1.3 Applying digital frontier technologies during the pandemic

AI and big data analytics

AI and big data analytics have been used to fight against the COVID-19 pandemic. China has used AI and big data analytics to support measures restricting the movement of populations, forecasting the evolution of disease outbreaks and research for the development of a vaccine or treatment. With regard to the latter, AI has been used to speed up genome sequencing, make faster diagnoses, carry out scanner analyses or, more occasionally, handle maintenance and delivery robots (Chun, 2020).

The predictions of the virus structure generated by AI have already saved scientists months of experimentation. The American start-up, Moderna, has distinguished itself by its mastery of a biotechnology based on messenger ribonucleic acid (mRNA) for
which the study of protein folding is essential. It has managed to significantly reduce the time required to develop a prototype vaccine testable on humans thanks to the support of bioinformatics, of which AI is an integral part (Johnson, 2021).

Similarly, the Chinese technology giant Baidu, in partnership with the Oregon State University and the University of Rochester, published its Linearfold prediction algorithm, in February 2020, to study the same protein folding. This AI algorithm is much faster than traditional algorithms in predicting the structure of a virus’ secondary ribonucleic acid (RNA) and provides scientists with additional information on how viruses spread (Council of Europe Portal, 2021).

The Alibaba DAMO Academy, the research arm of the Chinese company Alibaba, has also trained an AI system to recognize coronaviruses with a claimed accuracy of 96 per cent. According to the company, the system could process the 300 to 400 scans needed to diagnose a coronavirus in 20 to 30 seconds, whereas the same operation would usually take an experienced doctor 10 to 15 minutes. The system is said to have helped at least 26 Chinese hospitals to review more than 30,000 cases (Li, 2020).

In the Republic of Korea, AI is reported to have helped reduce the time needed to design testing kits based on the genetic make-up of the virus to a few weeks, when it would normally take two to three months (Watson and others, 2020).

**Internet of Things (IoT)**

IoT can play an important role in the transportation and storage of the COVID-19 vaccine. If COVID-19 vaccines are exposed to temperatures outside the range prescribed for storage and transport, at any point en route from the manufacturer to the recipient, they could become unusable. IoT provides a useful solution in this respect. For example, in Thailand, IoT Cold Chain has been used to monitor temperature and control the Cold Chain, which helps maintain the efficiency of COVID-19 vaccine storage. The innovation applies wireless seismic survey, a technology that is used during petroleum exploration to acquire the geological structure of rock layers. For the IoT Cold Chain, vibration sensors are replaced with temperature sensors. Installed within vaccine storage units, it ensures the temperature stays at the prescribed range and reports real-time data to control monitors. In case of irregularities, concerned personnel will be alerted for prompt response while the data will be sent to the central control centre that is linked with all devices in use in different parts of the country (Bangkok Post, 2021).
1. Introduction
2. Opportunities for harnessing digital frontier technologies for sustainable development
Opportunities for harnessing digital frontier technologies for sustainable development

Digital frontier technologies are already demonstrating their potential application for sustainable development. This section discusses the potential economic, social and environmental benefits of digital frontier technologies in the context of the 2030 Agenda for Sustainable Development.

2.1 Economic development

Technologies and innovation are central to long-term economic growth. The adoption of technologies and innovation in production processes increases overall productivity and expands production possibilities. Technological capabilities, comprising the ability and effort of mastering new technologies, adapting them to local conditions, improving upon them, diffusing them within the economy and exploiting them overseas by manufactured export growth and diversification, and by exporting technologies themselves, are fundamental to maintain broad economic growth.

From an economic perspective, a nation’s competitiveness depends on the capacity of its industry to innovate and upgrade. As shown in Figure 3, national competitiveness is
highly correlated with national innovation capability; two global indicators, the Global Competitiveness Index and the Global Innovation Index, are used to illustrate the point. Figure 3 shows that the large or advanced economies in the Asia-Pacific region, including Singapore, Japan, the Republic of Korea, Australia, New Zealand and China score well in terms of both national competitiveness and innovation (see top right corner of the figure).

Figure 3. National competitiveness and innovation capability


Note: Global Competitiveness Index uses a 1-7 scale while Global Innovation Index uses a 0-100 scale (higher average score means higher degree of competitiveness or innovation).

However, technological progress has not always been reflected in traditional economic indicators (Figure 4). As economist Robert Solow stated, “You can see the computer age everywhere but in the productivity statistics”. Other researchers point out that the traditional indicators, such as Gross Domestic Product (GDP), are not adequate to measure the benefits derived from Internet usage and modern technologies. For instance, the Internet provides rich information on almost every aspect of life, while most information is free of charge and is not counted as GDP (or productivity) (Box 3).
2. Opportunities for harnessing digital frontier technologies for sustainable development

Figure 4. Growth of labour productivity per hour worked

Note: Five-year moving average of median growth of labour productivity per hour worked, in percentage terms, in 87 countries.

Box 3. Debate on the impacts of innovation and technology

The book “The Rise and Fall of American Growth” has drawn wide attention. “Whether or not you end up agreeing with Gordon’s thesis, …this book will challenge your views about the future; it will definitely transform how you see the past”, wrote economist Paul Krugman in The New York Times.a

In this book, the author, Robert Gordon, argues that the age of great American productivity is over and predicts that the future would not live up to the past in terms of economic growth.

Amongst the many readers of the book, Bill Gates, found “his historical analysis, which makes up the bulk of the book, utterly fascinating”. However, Bill Gates disagreed with the analysis of the future, and commented that “Gordon uses something called Total Factor Productivity (TFP), …while economic measurements like TFP can be useful for understanding the impact of a tractor or a refrigerator, they are much less useful for understanding the impact of Wikipedia or Airbnb”.b

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2. Opportunities for harnessing digital frontier technologies for sustainable development

2.2 Social impact

Transforming public service delivery

The advent of the Internet, in the mid-1990s, triggered the rapid diffusion of e-government systems to automate core administrative tasks, improve the delivery of public services, and promote transparency and accountability.

As the COVID-19 pandemic forced lockdowns, most countries and municipalities worldwide began to pursue digital government strategies, many with innovative initiatives. In responding to the health emergency, governments put in place new tools, such as dedicated COVID-19 information portals, hackathons, e-services for the supply of medical goods, virtual medical appointments, self-diagnosis apps and e-permits for curfews. Many countries were quick to deploy tracking and tracing apps, and apps for working and learning from home. Among the least developed countries, Bhutan, Bangladesh and Cambodia have become leaders in digital government development, advancing from the middle to the high E-Government Development Index (EGDI) group, in 2020 (DESA, 2020).

Digital technologies can strengthen government capability and empower citizens through three mechanisms: 1) they overcome information barriers and promote participation by citizens in services and in elections; 2) they enable governments to replace some factors used for producing services through the automation of routine activities, particularly discretionary tasks vulnerable to rent-seeking, and to augment other factors through better monitoring, both by citizens through regular feedback on service quality and within the government through better management of government workers; and 3) they enable citizens to connect with one another at an unprecedented scale, fostering citizen voice and collective action, by dramatically lowering communication costs through digital platforms (World Bank, 2016).

Reducing inequality and supporting inclusion

The relationship between technology and inequality is multifaceted. Technology has brought equality dividends by enabling productive transformation and rapid economic growth in the region. Technologies, notably ICT, have brought improved access to basic services, such as finance and education, and are preventing and mitigating the environmental hazards that often disproportionately affect the poor. However, technology could widen inequalities as countries differ in terms of investments, policy support or technological capabilities; or because technology is skill- and capital-biased and enables rent seeking; or because certain conditions need to be in place before vulnerable populations can benefit from technology, including ICT infrastructure, skills and access to appropriate technological solutions.
Nevertheless, governments are using digital technologies to reduce inequalities and support inclusion. As an example, the Aadhaar technology has enabled the financial inclusion of 1.2 billion people in India. The Aadhaar programme in India is a government-led, technology-based financial inclusion system. The system includes a unique identification number (based on biometric and demographic data) linked to a mobile phone number, a low-cost bank account, and an open mobile platform. The combination of those elements enabled public and private banks to establish an open and interoperable low-cost payment system that is accessible to everyone with a bank account and a mobile phone. More than 338.6 million beneficiaries have now received direct benefit transfers, saving the Government $7.51 billion over three years (Government of India, 2017).

2.3 Environmental protection

Digital frontier technologies have the potential to be applied for environmental protection. Governments in Asia and the Pacific have promoted the adoption of state-of-the-art technologies to address environmental impacts. For instance, in the Republic of Korea, the entire smart city of Songdo is built around the Internet of Things. Among other benefits, smart cities reduce traffic pollution; save energy and water and create a cleaner environment.

For environment and climate, AI and deep learning can help climate researchers and innovators test out their theories and solutions for reducing air pollution. One example of this is the Green Horizon Project from IBM that analyses environmental data and predicts pollution, as well as testing “what-if” scenarios that involve pollution-reducing tactics. By using the information provided by machine-learning algorithms, Google was able to cut the amount of energy it used at its data centres by 15 per cent. Similar insights can help other companies reduce their carbon footprint (Marr, 2018).

In the transport area, AI is already being used in smart transport, for example, Google maps, where machine-learning algorithms are used to optimize navigation, increase safety and provide information regarding traffic flows and congestion.

For biodiversity and conservation, when combined with satellite imagery, AI can detect changes in land use, vegetation, forest cover, and the effects of natural disasters. Invasive species can be monitored using the AI technology, their presence can be identified and tracked, and they can be eliminated using machine learning and computer vision. A company called Blue River Technology is using AI to detect the presence of invasive species and other changes in biodiversity (Chopra, 2021).

Big data analytics have been applied to support environmental protection. For example, UNEP’s World Environment Situation Room, a platform which was put together by a consortium of Big Data partners in 2019, includes geo-referenced, remote-sensing and Earth observation information and collates climate data in near real-time (United Nations Environment Programme, 2021).
3. Challenges of harnessing digital frontier technologies for sustainable development
3. Challenges of harnessing digital frontier technologies for sustainable development

To effectively develop and implement digital frontier technologies for sustainable development, challenges vary depending on the context in a country or industry. This section covers three common areas where impacts of digital frontier technologies may not necessarily produce sustainable development results, namely, 1) the impacts of digital frontier technologies on jobs, 2) a new digital frontier technology divide, and 3) issues of ethics and trust.

3.1 Impact of digital frontier technologies on jobs

The significance of the impact of digital frontier technologies on jobs has long been recognized. In 1933, John Maynard Keynes voiced concerns regarding technological unemployment (Keynes, 1933). Today, debates on the impact of digital frontier technologies on jobs are ubiquitous (see the list of studies in Appendix 1). The World Bank estimates that up to two-thirds of all jobs are susceptible to automation in the developing world in the coming decades from a pure technological standpoint (World Bank, 2016). Results from a firm-level survey suggest that automation may have significant impacts on 60 to 89 per cent, depending on the
countries and sectors, of the job security of salaried workers in the following 5 major sectors of the Association of Southeast Asian Nations (ASEAN) economies: automotive and auto parts; electrical and electronics; textiles, clothing and footwear; business process outsourcing; and retail (Chang, Rynhart and Huynh, 2016). A more recent study shows that 12 per cent of the jobs in Asia could be eliminated with the development of AI (MIT Technology Review, 2019).

It is important to note that the estimation results vary according to the sampling and analytical methodologies. For instance, different studies show that 7 to 55 per cent of the jobs in Japan could be lost to automation. Therefore, the results of the existing studies need to be interpreted with caution (Figure 5).

Figure 5. Range of estimates of the share of jobs at risk of being lost to automation

Source: Compiled by the ESCAP study team according to the existing studies, as shown in the figure.
Note: The sample in the figure include countries in the ESCAP region. Detailed data are shown in Appendix 1.
Jobs in less developed countries are more susceptible to automation than in more advanced countries

Figure 5 shows that jobs in developing countries, especially the least developed countries, are more susceptible to automation from a technical perspective. For example, various studies in Nepal have estimated that either 41 per cent or up to 80 per cent of the jobs, can be automated. Similarly, the World Bank and the International Labour Organization have different estimations, ranging from 41 per cent, 57 per cent and 78 per cent, of jobs in Cambodia that can be automated (World Bank, 2016; Chang, Rynhart and Huynh, 2016). In contrast, in advanced economies, such as Japan and the Republic of Korea, some studies estimate that less than 10 per cent of the jobs will be lost to automation.

From a technical perspective, a job can be more easily automated if the relevant activities and tasks are routine (UNCTAD, 2017). Based on an OECD survey that asked workers about the intensity of tasks in their daily work that can be clearly regarded as routine and follow predefined patterns, the manufacturing sectors with the greatest intensity in routine tasks were identified as food, beverages and tobacco; textiles, apparel and leather; and transport equipment (top left of Figure 6) (OECD, 2016b).

Figure 6. Proximate relationship between technical and economic feasibility of routine task automation and estimated stock of industrial robots, by manufacturing sector

Note: The axes have no scaling to underline the proximate nature of the relationship shown in the figure. Bubble sizes reflect the stock of industrial robots.
What is technically feasible is not always economically viable

Despite the numerous forecasts on how automation or robots will replace human labour, many existing studies mainly focus on the technical feasibility of job displacement while neglecting the factor that what is technically feasible is not always economically viable (UNCTAD, 2017).

For instance, robot deployment is largely decided by economic feasibility. Robot deployment has remained very limited in those manufacturing sectors where labour compensation is low, even if these sectors have high values on the routine-task intensity. Robot deployment in the textiles, apparel and leather sector has been lowest among all manufacturing sectors even though this sector ranks second in terms of the technical feasibility of automating routine tasks of workers.

AI provides another example. AI has been mainly developed and applied in a few sectors in several advanced economies. Therefore, AI has had limited impacts on job markets in many developing countries. Even in AI-advanced countries, according to a survey conducted by McKinsey of 3,000 AI-aware C-level executives across 10 countries and 14 sectors, “the majority of firms did not expect artificial intelligence to significantly reduce the size of their workforce” (Woetzel and others, 2017). The MIT Technology Review has also highlighted that “artificial intelligence has so far been mainly the plaything of big tech companies like Amazon, Baidu, Google, and Microsoft, as well as some start-ups. For many other companies and parts of the economy, artificial intelligence systems are too expensive and too difficult to implement fully” (MIT Technology Review, 2018).

However, it is important to note that the current low adoption of AI is reflective of the fact that the industry is still at the nascent or pilot stage of development. This should not be confused with the possible wider application of AI technology in the future. Indeed, diffusion patterns for successful technologies generally follow a distinctive “S” shape; the rate of adoption is initially slow and confined to so-called first adopters, increasing rapidly as the technology becomes established, but then slowing as markets approach saturation, with only harder-to-reach or resistant adopters left (Institute of Development Studies, 2016).

Ultimately, decisions on the adoption of automation technologies often hinge on cost-benefit analysis. Figure 7 provides a schematic analysis of costs for the adoption of automation technologies or human labour. Assuming labour costs keep rising while automation costs keep decreasing, the equilibrium is first achieved in more advanced economies between regular automation and labour (point A). This means, from a cost-benefit perspective, advanced economies are more likely to adopt regular automation after this point. The equilibrium is achieved later in a less developed country (point B). Given the high costs, AI-automation tends to be adopted later than regular automation (point A versus point C or point B versus point D). Again, advanced economies tend to adopt AI-powered automation earlier than less advanced economies.
3. Challenges of harnessing digital frontier technologies for sustainable development

The digital frontier technological transition is not a question of “if” but “when”

In short, the nature of technological displacement of labour is about how fast, rather than whether, it will happen. Market mechanisms will dictate that start-ups, SMEs, corporations and industries choose the most cost-effective method of production. Governments need to be proactive in analysing the pace and scale of automation and put responsive and adaptive policies in place (further elaborated in the section titled “Policy Priorities”).

Although the prevailing narrative is that more and more jobs will be lost to machines, it is also a distinct possibility that, in the future, humans and machines work together. A joint study by United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and Google provides a case study on how an AI tool, named TradeMarker, helped decrease the workload and labour time required of the Trademarks Office of the Justice Department to handle all incoming requests for new trademarks in Israel (ESCAP and Google, 2019). TradeMarker significantly shortened the examination process of new trademark requests, and supported human decision makers, rather than automating decisions. This case shows the immense value derived from augmentation rather than full automation or replacement of labour.

In addition, lessons derived from history suggest that we may have yet to imagine the industries of the future and the new jobs that economies will demand.

Figure 7. A schematic analysis of costs for the adoption of AI-powered automation or labour

![Figure 7. A schematic analysis of costs for the adoption of AI-powered automation or labour](image)

3.2 A new digital frontier technology divide

The digital divide

Despite the rapid penetration of the Internet globally, several billion people have been left behind with no access to the Internet. As ICT infrastructure is the backbone of many digital frontier technologies, there is a risk of a new digital frontier technology divide on the back of an already existing one. For example, there is diversity in the fixed broadband subscriptions per 100 inhabitants in the Asia-Pacific region. Countries such as the Republic of Korea, Australia, Japan and China have high rates of broadband subscriptions, however, some countries, such as Afghanistan, Bhutan, Cambodia, India, Kiribati, the Lao People’s Democratic Republic, Pakistan, Solomon Islands and Timor-Leste have less than two broadband subscriptions for the same indicator (Figure 8).

The spectrum of R&D expenditure in the region

Another perspective to assess the digital frontier technology divide is gross domestic expenditures in research and development (R&D) as a percentage of GDP (Figure 9). Of the 14 countries for which data are available for 2018, only 3 countries in the region, China, Japan, and the Republic of Korea, spent 2 per cent or more of their GDP on R&D. On the other end of the spectrum, half of the countries spent 0.25 per cent or less on R&D. These countries include Armenia, Azerbaijan, Indonesia, Mongolia, Kazakhstan, Tajikistan and Uzbekistan.

Technology diffusion to the poor

Technology diffusion is rarely automatic. Among other reasons, some technologies, despite their technical superiority, may not be commercially viable or affordable for some groups of people or communities. In extreme cases, some technologies may not go beyond the laboratory. Also, the technology life cycle, often depicted as an S-Curve and divided into several stages: development, market introduction, growth, maturity and sometimes decline, means new technologies are often only accessible to a small group of people or sectors before mainstream adoption. One of the most prominent examples of this theory is that it took 30 years for electricity and 25 years for telephones to reach 10 per cent adoption in the United States of America (World Bank, 2016).

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1 For instance, a survey conducted by Facebook in 2015 estimated that 4 billion people have no access to the Internet. See Arwen Armbrecht, "4 reasons 4 billion people are still offline", World Economic Forum, 23 February 2016. Available at https://www.weforum.org/agenda/2016/02/4-reasons-4-billion-people-are-still-offline/. World Bank (2016) estimated that nearly 6 billion people do not have high-speed Internet.
3. Challenges of harnessing digital frontier technologies for sustainable development

Figure 8. Fixed-broadband subscriptions per 100 inhabitants in ESCAP member countries

On the other hand, evidence has shown that technology adoption has been accelerating. It took decades for the telephone to reach 50 per cent of households, beginning before 1900. However, it took five years or less for cellphones to accomplish the same penetration in 1990 (Figure 10). Similarly, technologies, especially digital technologies, have been spreading more rapidly than before in developing countries (Figure 10). Nearly 70 per cent of the bottom fifth of the population in developing countries own a mobile phone. In addition, the number of Internet users has more than tripled in a decade from 1 billion users, in 2005, to an estimated 3.2 billion users at the end of 2015 (World Bank, 2016).

Despite such achievements, there are wide gaps among developed and less developed countries in adopting technologies. As shown in Figure 11, high-income or wealthy countries (measured by GDP per capita) demonstrated better adoption of technologies.

The central tenet of the Sustainable Development Goals (SDGs) is to “leave no one behind”. If market forces dominate, the poor may be the last group who benefit from digital frontier technologies. Policy interventions should guide digital frontier technologies to serve and benefit those who generally cannot afford them if the ambitions of the 2030 Agenda for Sustainable Development are to be met. (Further discussion on this is available in Section 4.7).
3. Challenges of harnessing digital frontier technologies for sustainable development

Figure 10. Technologies are spreading rapidly in developing countries

![Graph showing the diffusion of digital technologies across countries](image)


Figure 11. Adoption of technologies by countries worldwide

![Graphs showing adoption by businesses, people, and governments](image)


Note: The figures show the diffusion of digital technologies across countries as measured by the Digital Adoption Index. The sample cover 172 countries worldwide.
3.3 Ethical issues

The digital frontier technologies discussed in this report are associated with various ethical issues. For Internet of Things, as the information is shared among devices connected to the Internet, there are concerns relating to data security and privacy. Also, ownership and management of data can be problematic. For instance, the owner of an Internet-connected device may not be clear what data is collected by service providers and how the data are used.

Ethical issues on AI have also attracted much debate. Topics have included:

- The existential risk for mankind: The late physicist, Stephen Hawking, warned of the importance of regulating AI stating, “The development of full artificial intelligence could spell the end of the human race” (Cellan-Jones, 2014).
- Bias: Experts have highlighted that bias could be the real AI danger. John Giannandrea, the former Google AI Chief, commented that, “the real safety question, if you want to call it that, is that if we give these systems biased data, they will be biased” (Knight, 2017a).
- Unpredictable and inscrutable nature of AI: Sophisticated AI algorithms mean, in some situations, that the designers or engineers of the algorithm cannot explain how the AI system makes decisions. This certainly carries risks. For instance, what decisions will a driverless car make when there is an emergency?

Balancing privacy and openness of data is a common ethical dilemma for all the digital frontier technologies discussed in this report. The data made available through the open and big data movements has combined with advancements in computing, machine learning and behavioural economics to fuel the growth of several digital frontier technologies. How governments manage data, now and in the future, will be important. Striking the right balance between privacy, ownership and transparency is a difficult task.

At the global level, there are challenges for collecting, disseminating and storing data, especially for vulnerable communities in times of crises. The issues surrounding the security and privacy of data collected in a hostile, conflict environment are even more critical to address, as there is often a need to protect informants; safeguard information from manipulation; and employ mechanisms to ensure the veracity of the data collected and utilized.
3. Challenges of harnessing digital frontier technologies for sustainable development
Policy priorities

While there are question marks over the scale and pace of the digital frontier technological transition, it would be prudent for governments to be prepared, and to put effective policies in place. As stated by the Nobel laureate Robert Shiller, “[w]e cannot wait until there are massive dislocations in our society to prepare for the Fourth Industrial Revolution” (Hutt, 2016).

Technology and innovation underpin the Fourth Industrial Revolution and national science, technology and innovation (STI) policies should provide a guide to all stakeholders in preparing for the impacts and transitions toward using digital frontier technologies.

National STI policies serve several functions. First, they articulate a government’s vision regarding the contribution of STI to their country’s social and economic development. Second, they set priorities for public investment in STI and identify the focus of government reforms. Third, the development of these strategies can engage stakeholders ranging from the research community, funding agencies, business, and civil society to regional and local governments in policymaking and implementation. In some cases, national strategies outline the specific policy instruments to be used to meet a set of goals or objectives. In others, they serve as visionary guideposts for various stakeholders (OECD, 2016a).

National innovation systems theory has traditionally been the guideline for developing STI policy. A next generation technology policy framework is required for the Fourth Industrial Revolution future that we face. To date, several countries in the region have shown strong political will to develop policies for specific digital frontier technologies. A few examples are highlighted as follows:
4. Policy priorities

- In 2017, China published a comprehensive AI development policy with the overarching goal to make the country “the front-runner and global innovation centre in AI”, by 2030 (State Council, 2017b).

- Japan’s Artificial Intelligence Technology Strategy Council was launched in April 2016. The Council subsequently developed the Artificial Intelligence Technology Strategy, which was published in 2017 (Strategic Council for AI Technology, 2017). The strategy outlines some of the priority areas for Japan in the areas of AI research and development, and promotes collaboration between relevant government agencies, industry and academia in order to further AI research. Japan has also proposed setting up an international set of basic rules for developing AI (The Japan Times, 2016).

- In the Republic of Korea, the Ministry of Science and ICT has also laid out the “Artificial Intelligence Information Industry Development Strategy”, which aims to strengthen the foundation for AI growth (Lee and Choi, 2016). In 2016, the Government also published their “Intelligence Information Society Fourth Industrial Revolution Medium- to Long-term Comprehensive Response Plan” (Ministry of Science and ICT, 2017).

Countries in the Asia-Pacific region are also developing roadmaps, plans and standards for IoT. These include:

- The ASEAN ICT Masterplan 2020 which emphasizes that ASEAN will provide leadership in responsible development through the promotion of interconnected Smart Cities. Green policies will be promoted through the deployment of next generation ICT, such as sensor networks and IoT (ASEAN, 2016).

- Australian authorities freed up additional spectrum bands dedicated to the use of IoT in December 2015 (Australian Communications and Media Authority, 2015).

- India’s Internet of Things Draft Policy, 2015: The Government is driving the adoption of IoT by investing in smart cities and promoting start-ups. In collaboration with the private sector, it established a Centre of Excellence for Internet of Things (Sahay and Pola, 2020).

- In Japan, with a view toward the arrival of a full-fledged IoT society, the National Center of Incident Readiness and Strategy for Cybersecurity formulated and published a “General Framework for Secure IoT Systems” in March 2016, and the IoT Acceleration Consortium published a set of “IoT Security Guidelines” in July 2016. These also include the content of the “IoT” series published by the IT Knowledge Center of the Information-technology Promotion Agency (IPA). To ensure the safety and security of an IoT society being recognized internationally, Japan proposed a standard based on the IoT Security Guidelines etc., and a standard based on the


- In Malaysia, the National IoT Roadmap aims to realize the vision of Malaysia as the Premier Regional IoT development hub with the mission of creating a national ecosystem to enable the proliferation of use and industrialization of IoT as a new source of growth for the national economy. There are three main goals for the implementation of the National IoT Strategic Roadmap: (i) create a conducive IoT industry ecosystem to stimulate the smooth implementation of IoT technology; (ii) strengthen technopreneur abilities and capabilities in Apps and services development based on IoT technology; and (iii) develop Malaysia as the Premier Regional IoT development hub.2

- New Zealand’s Business Growth Agenda 2017 includes initiatives to accelerate the adoption of IoT technologies through market research and the establishment of an Internet of Things Alliance, which is a collaboration between the industry and the government.3

- Singapore has developed a suite of IoT standards published as Technical References (TRs) for IoT and sensor networks. These TRs aim to address the absence of any coherent sensor networks or IoT standards, with a focus on interface interoperability. While there are no lack of IoT-related standards or interoperable sensor network systems and services globally, there is a lack of a blueprint on how various disparate standards can be combined to enable an eco-system of interoperable sensor network devices and systems. These TRs focus on open standard interfaces between the devices and systems, and should help to reduce cost of deploying, operating and maintaining sensor applications.4

While these policies and strategies are very technology specific, as an initial step towards understanding the policy response to the opportunities and challenges that

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digital frontier technologies present more broadly, this section discusses seven key policy areas that could form the backbone of a next generation technology policy. Such policies focus on creating an enabling environment for digital frontier technologies and are aligned to sustainable development objectives.

The seven policy priorities are:

1. Inclusive ICT infrastructure;
2. Developing a workforce fit for a Fourth Industrial Revolution future;
3. Developing innovative regulatory frameworks;
4. Incentivizing responsible digital frontier technology development in the private sector;
5. Catalysing the role of government in the evolution of digital frontier technologies;
6. Creating a platform for multi-stakeholder and regional cooperation; and
7. Making digital frontier technologies serve the poor and the least developed countries.

4.1 Inclusive ICT infrastructure

A prerequisite for the development and application of digital frontier technologies is an established ICT infrastructure. As shown in Figure 9, ICT usage is unequally distributed among countries. High-income countries, those that are at the forefront of digital frontier technology development, have seen very rapid increases in the development of ICT infrastructure, while middle-income countries, after a slow start, are experiencing steeper increases. The situation in low-income countries on average, remains unchanged.

Even if middle-income and to some extent low-income countries are not at the forefront of developing digital frontier technologies, equalizing opportunities embedded in the possibility of buying such technology or adapting parts of it to local circumstances could be lost if digital infrastructure deficits persist. In this regard, a continued focus on bridging the digital divide – particularly “last mile” connectivity – should be a policy priority so as not to fuel a new frontier technology divide.

4.2 Developing a workforce fit for a Fourth Industrial Revolution future

While the scale and pace of frontier technological adoption and diffusion are still unknown, it would be prudent for governments to develop a workforce fit for a Fourth Industrial Revolution future. Some directions to consider include: a great emphasis on entrepreneurship training to develop job creators as well as job seekers, adult
education, life-long learning, and reskilling to deal with current and future technological transitions. Education must also instil new expectations about work and the marketplace for jobs. This will require innovative education policies (Box 4).

### Box 4. How Singapore Encourages Lifelong Learning and Workforce Resilience

The Government of Singapore has been actively facilitating life-long learning. SkillsFuture Singapore (SSG), for example, is a statutory board under the Ministry of Education that provides an array of lifelong learning and workforce development programs for people of all ages, including students, early-to-mid career professionals, and even seniors.

In 2017, the Committee for the Future Economy (CFE) published an extensive report that highlighted workforce development as a critical priority area for the government. The CFE report made specific policy recommendations for ensuring that Singaporeans have the resources to pursue lifelong learning opportunities. It encouraged educational institutions and training providers to work closely with industry to ensure that their programs are matched to market needs.

Singapore’s institutions of higher learning are also making efforts to support and inspire lifelong learning and workforce resilience, both for their current students and the broader Singapore community. The National University of Singapore (NUS), for example, launched the School of Continuing and Lifelong Education (SCALE) in 2015, to expand its offerings for working adults.

*Source: Kamei, 2017.*

### 4.3 Developing innovative regulatory frameworks

**Responsive and adaptive regulation**

To avoid hindering the development of digital frontier technologies’ application for sustainable development, regulatory processes need to become responsive and adaptive. However, enabling regulation for innovation is difficult to formulate and as such, innovations in regulation processes are urgently required. For example, the Fintech Supervisory Sandbox, launched by the Hong Kong Monetary Authority in 2016, allows banks and their partnering tech firms to conduct pilot trials of their FinTech initiatives without the need to achieve full compliance with supervisory requirements in early-stage development. This arrangement enables banks and tech firms to gather data and user feedback so that they can make refinements to their new initiatives, thereby expediting the launch of new technology products, and reducing development costs.
Effective regulation should allow innovation to flourish while still safeguarding society and the environment. Balancing these demands will be an important government agenda as digital frontier technologies evolve, and one that will require sharing effective practices and innovative approaches between governments. Responsive and adaptive regulation may provide a solution as it emphasizes that policies need to support the development of digital frontier technologies while also allowing for faster responses to ensure that the public is not exploited and that new dangers are averted (Mulgan, 2017).

Digital frontier technology ethics

Governments have already begun to tackle the ethical issues highlighted in this report. For example, in Germany, the Federal Government has proposed rules for decision-making to promote ethical behaviour by systems guiding crash scenarios for driverless cars. These rules prioritize human life above property damage and do not discriminate between human lives. Although industry is driving advances in AI technology, governments must play a key role in ethical and governance considerations. The consensus of member States on standards and ethical principles for technological advancements will be critical to ensure that technological transitions are well-managed.

4.4 Incentivizing responsible development of digital frontier technology in the private sector

Shared value

As the predominant investor in digital frontier technologies, the private sector will shape its impact on the economy, the society and the environment. However, to create positive impacts on these three dimensions of sustainable development, corporations need to move beyond the concept of corporate social responsibility and redefine their objective, and associated measures of success, as creating “shared value” (Porter and Kramer, 2011). Shared value is different from corporate social responsibility. It measures value across the three dimensions of sustainable development at the core of business strategy. To further promote shared value, policymakers need to create the right incentives, so these values move from corporate social responsibility departments to the boardrooms.

Governments can play a critical facilitating role by creating an environment to ensure that the development, adaptation and diffusion of digital frontier technologies, by the private sector, is appropriate to their own country context. Typical measures can include subsidies or tax incentives for the development of products by the private sector which bring substantial societal or environmental benefits, especially those related to the SDGs.
4. Policy priorities

Public-private partnerships

Past experiences show that public-private partnerships may provide alternatives to financing the development of digital frontier technologies. For example, a public-private partnership that combined government funding and policy direction with private infrastructure investment and management underpinned the success of the Republic of Korea’s fixed broadband penetration. The Government invested less than $1.8 billion, compared with over $33 billion from the private sector, in establishing the backbone network serving larger cities from 2005 to 2014 (World Bank, 2016).

Public-private partnership can take many forms. For instance, a government can promote and drive joint research with the private sector and the academia in areas of strategic national interest or direct effects on public goods. Governments may also provide support to the private sector for the implementation of pilot projects.

Engaging the technology giants

Leading technology companies could be important partners for addressing the SDGs. Efforts by leading global technology companies to make digital frontier technologies publicly available and transparent would enable developing countries to learn about the latest developments and identify solutions to social and environmental issues. An important example in this respect is the Partnership on AI to Benefit People and Society founded by Amazon, Apple, DeepMind, Facebook, Google, IBM and Microsoft, in 2016. The partnership states that its goals are to study and formulate best practices on the development, testing, and fielding of AI technologies, to advance the public’s understanding of AI, to serve as an open platform for discussion and engagement about AI, and its influences on people and society, and to identify and foster aspirational efforts in AI for socially beneficial purposes. In Asia, Huawei published its first report dedicated to technology for sustainable development, in 2017, and stated that, “It is our responsibility to support the UN in its pursuit of the Sustainable Development Goals, and it’s one that we take seriously” (Huawei, 2016).

On the other hand, technology companies, such as Amazon, Google, Facebook, Alibaba and eBay, dominate their respective sectors. This may restrain effective market competition and lead to winner-take-all market outcomes. Indeed, some companies have been subjected to anti-trust investigations. While the important role of the private sector in sustainable development has been well noted, governments need to put effective policies in place to manage any potential conflicts between maximizing corporate objectives of increasing shareholder wealth, and potentially negative social and environmental impacts.
4. Policy priorities

4.5 Catalysing the role of governments in the evolution of digital frontier technologies

Public sector innovation skills

It will be critical for government and public sector workers to develop innovation skills if countries are to meet the diverse range of goals set out in the SDGs. Governments will need to support an agile, forward-thinking and technologically skilled civil service to respond to a rapidly changing world and the opportunities that digital frontier technologies present. While caricatures of public servants that depict them as hostile to innovation are out of date, public organizations need to continue to develop skills and better processes if they are to resist the tendency of inertia. The Government of Singapore’s Digital Services Team provides an example of an initiative by a government that has focused on bringing in non-traditional civil service skills. The team of software developers, user experience designers and architects build digital services using an agile project management method that emphasizes small changes to services based on feedback from user testing and research.

Digital literacy is a key skill that will enable governments to digitize many of their services, increasing effectiveness and efficiency. According to an e-government survey of the United Nations Department of Economic and Social Affairs (DESA), several countries in Asia and the Pacific top the survey’s list (Figure 12).

The government as a market maker and shaper

As highlighted previously in this report, the private sector has been the prime investor in digital frontier technologies. However, increasingly, governments in the Asia-Pacific region are establishing dedicated agencies to help realize the transformative potential of digital frontier technologies. One such agency is Singapore’s SGInnovate, which was launched in November 2016 as the venture capital arm of Singapore’s Infocomm Development Authority. This government-owned company specializes in supporting digital frontier technology and deep technology initiatives and start-ups in Singapore, with a focus on AI, robotics and blockchain. The creation of SGInnovate complements the Singaporean Government’s strategy to boost the country’s digital frontier technology capabilities, through its government-wide partnership and national programme on Artificial Intelligence Singapore. The initiative builds on Singapore’s vision of becoming a Smart Nation, as well as on the recommendations of the Committee on Future Economy to realize the growth opportunities of a digital economy and build stronger digital capabilities.⁵

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⁵ For more information on SGInnovate, see https://www.sginnovate.com/.
Figure 12. E-Government Development Index 2020

4. Policy priorities

4.6 Creating a platform for multi-stakeholder and regional cooperation

Cross-government cooperation, inter-governmental knowledge-sharing and consensus-building, and honest, open and regular discussion with civil society and the private sector, specifically technology developers, will be critical to ensure that digital frontier technologies have a positive impact on sustainable development.

As a first step, developing a set of overarching principles governing the development of digital frontier technologies should be a first order priority. Globally, leadership on such an endeavour has been sub-optimal. However, given Asia and the Pacific's prominent position in several digital frontier technologies, the region is well placed to lead on governance globally, to build trust and ensure effective deployments aligned with the SDGs.

As an example, during Japan’s 2016 Group of Seven presidency, the Minister of Internal Affairs and Communications proposed some basic principles that could guide AI research and development. The principles, which were presented during the Group of Seven ICT Ministers meetings, held in April 2016 in Takamatsu, Kagawa Prefecture, Japan, were an outcome of ongoing studies on the benefits and impacts of AI networking on the Japanese society and economy. Similarly, in the United Kingdom, several recommendations on the ethical principles of AI are being proposed (Box 5).

Box 5: The artificial intelligence research and development principles/guidelines proposed by Japan to the Group of Seven countries and the United Kingdom

The intention of the guidelines proposed by Japan was to enhance the benefits and minimize the potential risk of artificial intelligence, in order to ensure the artificial intelligence research and development is human-centred and protects the interests of users. Given the rapidly developing nature of artificial intelligence technology, the guidelines should not be perceived as regulations, but rather proposed guidelines to be shared internationally as non-regulatory, non-binding soft law. The draft artificial intelligence research and development guidelines include:

1. Principle of collaboration – Developers should pay attention to the interconnectivity and interoperability of artificial intelligence systems.
2. Principle of transparency – Developers should pay attention to the verifiability of inputs/outputs of artificial intelligence systems and should be able to explain their judgements.
3. Principle of controllability – Developers should pay attention to the controllability of artificial intelligence systems.
4. Policy priorities

4. Principle of safety – Developers should take it into consideration that artificial intelligence systems will not harm the life, body, or property of users or third parties through actuators or other devices.

5. Principle of security – Developers should pay attention to the security of artificial intelligence systems.

6. Principle of privacy – Developers should take it into consideration that artificial intelligence systems will not infringe upon the privacy of users or third parties.

7. Principle of ethics – Developers should respect human dignity and individual autonomy in research and development of artificial intelligence systems.

8. Principle of user assistance – Developers should take it into consideration that artificial intelligence systems will support users and give them opportunities for choice in appropriate manners.

9. Principle of accountability – Developers should make efforts to fulfil their accountability to stakeholders including users of artificial intelligence systems.

The guidelines also call for governments and international organizations to promote dialogues amongst relevant stakeholders to promote common perceptions of the benefits of artificial intelligence and its challenges, and to review the guidelines and their operation. Furthermore, standardization bodies and other related entities are asked to prepare, and release recommended models that align with the proposed artificial intelligence guidelines. The guidelines also call for governments to support artificial intelligence developer communities in addressing challenges and mitigating the risks, and for policymakers to actively promote policies to support the research and development of artificial intelligence.\(^a\)

In the United Kingdom, a report “AI in the UK: Ready, Willing and Able?” prepared by the House of Lords Select Committee on Artificial Intelligence makes several recommendations on the ethical principles of AI namely: \(^b\), \(^c\)

1. Artificial intelligence should be developed for the common good and benefit of humanity.

2. Artificial intelligence should operate on principles of intelligibility and fairness.

3. Artificial intelligence should not be used to diminish the data rights or privacy of individuals, families, or communities.

4. All citizens should have the right to be educated to enable them to flourish mentally, emotionally, and economically alongside artificial intelligence.

5. The autonomous power to hurt, destroy or deceive human beings should never be vested in artificial intelligence.

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\(^b\) https://publications.parliament.uk/pa/ld201719/ldselect/ldai/100/100.pdf.

\(^c\) John Thornhill, “Britain urged to take ethical advantage in artificial intelligence”, Financial Times, 16 April. Available at https://www.ft.com/content/b21d1fb8-3f3e-11e8-b9f9-de94fa33a81e.
4.7 Making digital frontier technologies serve the poor people and the least developed countries

Often, the poor are the last group to gain access to new technology because of affordability. However, some solutions have been identified to make the poor benefit from the digital frontier technology. A joint study by ESCAP and Google presents a partnership between Microsoft and state governments in India to develop predictive AI services to help smallholder farmers in Southern India to improve their crop yields and give them greater price control (ESCAP and Google, 2019). The AI-sowing app generated advice on an “optimal sowing week”, gave recommendations based on pre-existing weather, soil and crop-yield data, and sent text messages to farmers with planting advice in their local language. The price forecasting model made predictions about crop yields to facilitate a non-partisan platform for price forecasting. In this case, the farmers benefit from the state-of-the-art AI services. More importantly, the best part of the project is that the investment required by the farmers to benefit from the technology is minimal: all they need is a mobile phone capable of receiving text messages, and a subscription to the most basic mobile phone services. Clearly, making technology accessible and affordable is a crucial step towards technology for inclusiveness.

In Thailand, there are around five million diabetic patients who are all at risk of vision loss if eye screening cannot be carried out regularly. However, Thailand has only around 1,400 eye doctors who can conduct such eye screening and most of these doctors are located in Bangkok. This means that many patients will not have access to eye screening regularly if they are to rely on the available doctors. To overcome this, Google, in collaboration with its partners in Thailand, has launched an AI project to conduct eye screening. This addressed the shortage of doctors and also provided a better diagnosis: research shows that the AI program has an accuracy rate of 95 per cent when it comes to disease detection, compared with 74 per cent from opticians or eye doctors (Tanakasempipat, 2018).

These two examples, although from the least developed countries, nevertheless, show that any developing countries and least developed countries can benefit from digital frontier technology if they adopt a policy to work with the private sector, especially the large technology companies. For instance, Google.org has issued an open call to organizations around the world to submit their ideas for how they could use AI to help address societal challenges. Selected organizations will receive customized support to help bring their ideas to life; coaching from Google’s AI experts; Google.org grant funding from a $25 million pool; credit and consulting from Google Cloud, and more (Google AI).
5. Conclusion
Conclusion

This report shows that digital frontier technologies hold great promise for contributing to sustainable development. However, there are challenges particularly regarding the future of work and jobs.

This report highlights that for many developing countries, especially the least developed countries, many jobs are still safe in the short term due to lower labour costs relative to the upgrading and transition costs of current digital frontier technologies.

In the long term, digital frontier technologies will have far reaching consequences throughout the Asia-Pacific region and across the globe. While there are questions concerning the scale and pace of the transition toward digital frontier technologies, it would be prudent for governments to prepare and put effective policies in place.

This report highlights policy areas that could form the basis of a next generation technology policy that is fit for the Fourth Industrial Revolution future that we face. Creating an enabling environment for digital frontier technologies to positively impact the economy, the society and the environment, and to reduce current and potential inequalities should also be a fundamental principle of future technology policy if it is to effectively support the SDGs. The broad contours of this framework could include a focus on:

1. Inclusive ICT infrastructure.
2. Developing a workforce fit for a Fourth Industrial Revolution future.
3. Developing innovative regulatory frameworks that do not stifle innovation and deal with ethical issues.
5. Conclusion

4. Incentivizing the private sector to pursue responsible digital frontier technology development.

5. Catalysing the role of government in the evolution of digital frontier technologies.

6. Creating a platform for multi-stakeholder and regional cooperation.

7. Making digital frontier technologies serve the poor people and the least developed countries.

The impacts of digital frontier technologies are far from pre-ordained. However, digital frontier technological breakthroughs require us to think differently about how we have traditionally formulated technology policy.

When developing policy on this agenda, it is important to note that concerns regarding the economic implications of emerging technologies are nothing new; textile workers destroyed looms in nineteenth century England for fear of losing their jobs and robots displaced workers on assembly lines. In this regard, we need to pay attention to historians, not just to futurists. It will be critical to learn from the past as we shape the future of digital frontier technologies.

Many countries are developing specific digital frontier technology policies and Fourth Industrial Revolution strategies. However, they are in their infancy. To support countries to prepare, the evaluation of the impact of these experimental strategies should be a policy priority to establish what works and, equally importantly, what does not. Through these activities, best practice next generation technology frameworks can be developed.

Finally, cross-government cooperation, inter-governmental knowledge sharing and consensus building, and honest, open and regular discussion with the civil society and private sector, specifically technology developers, will be critical to ensure that digital frontier technologies have a positive impact on long-term sustainable development.
## Appendix 1

### Existing studies on possible job losses to automation at country level

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<th>Jobs lost to automation (%)</th>
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Source: Compiled by ESCAP study team. The studies mentioned in this table are listed in the references.

Note: * Probabilities of automation from technical perspective; ** Probabilities of automation in the light of technical feasibility and pace of technology adoption.

Note: Country names are spelt as they appear in the respective studies.
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