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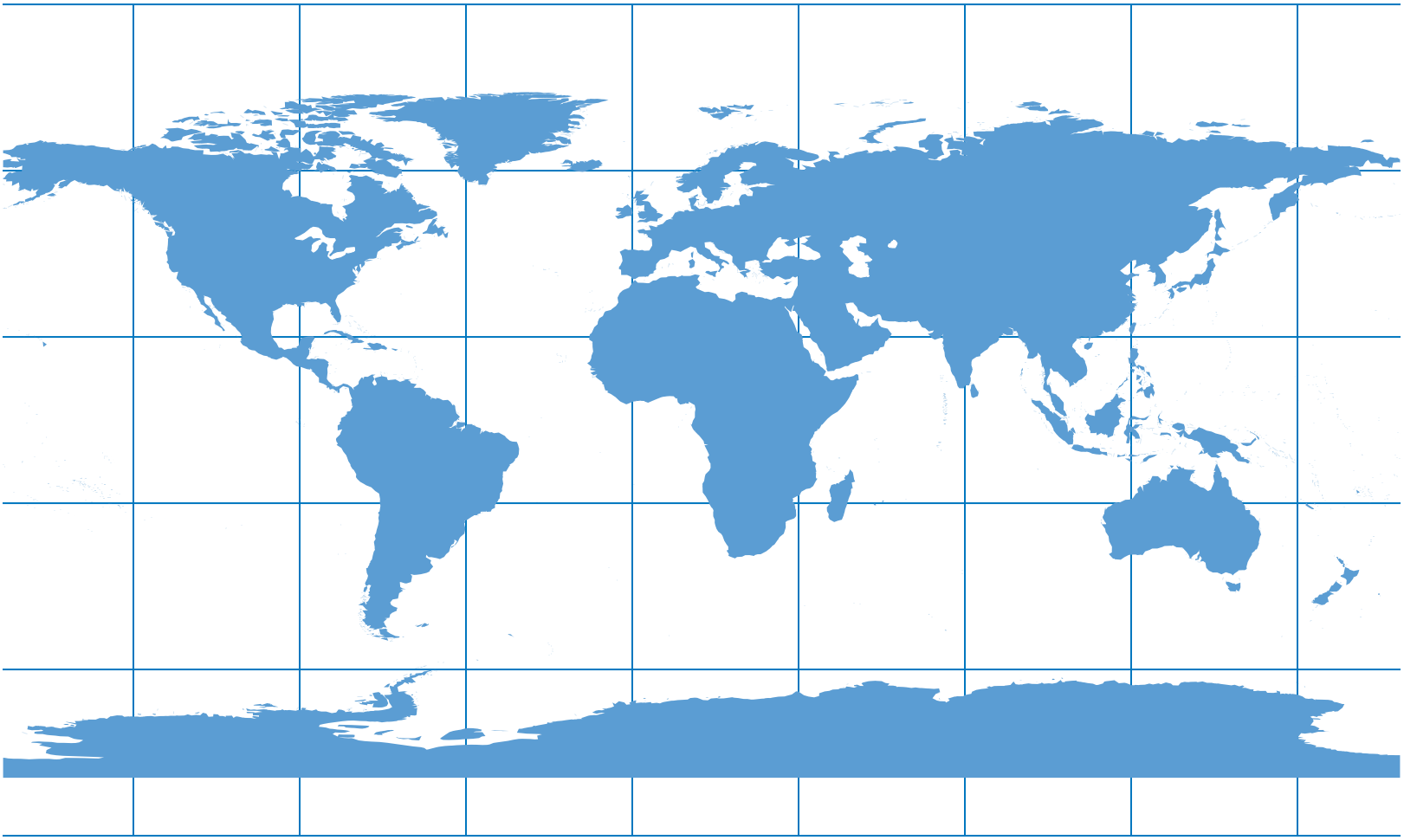
Frontier technologies for sustainable development



United Nations
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Chapter III

Bridging the development divide

Introduction

Frontier technologies can open up opportunities to close the technological divide and accelerate progress towards the SDGs

Major technological innovation has been led largely by several developed countries that are at the forefront of the technological frontier. Recently, however, developing countries, such as China and the Republic of Korea, have — in the areas of artificial intelligence (AI), autonomous vehicles, biotechnology, the Internet of Things, renewable energy technologies (RETs) and 3D printing — managed to push their way to the technological frontier. In the post-Second World War era, a dozen developing countries were able to advance into the category of high-income countries, several of which developed and strengthened national technological and innovation capacities to become key players in the development of new technologies. Bridging the technological divide has been a key development strategy for many of these countries. In fact, technological advances instil in many developing countries the great hope of bridging the development divide and catching up with developed countries.

The present chapter focuses on less developed countries, including the least developed countries (LDCs), landlocked developing countries (LLDCs) and small island developing States (SIDS) — referred to collectively as countries in special situations — and the challenges they face in taking advantage of existing technologies and managing the adoption of frontier technologies, as discussed in chapters I and II. In particular, renewable energy technologies, biotechnology and digital technology such as AI and crowd-based technologies can open up opportunities for these countries to close the existing technological divide, and to accelerate progress towards the Sustainable Development Goals (SDGs).

Many of these countries are yet to fully absorb the technologies of previous industrial revolutions, and there are significant technological divides that represent a barrier to the development and adoption of the new technologies. For example, more than 1 billion people are yet to have access to electricity and an additional 2.5 billion are described as "under-electrified", i.e., they are in a situation where connections are weak and power outages are common (*The Economist*, 2015). Many people in these countries depend on rain-fed agriculture and use bullock power for cultivation. Reliable sources of electricity are a necessary pre-condition for these countries with respect to climbing up the technological ladder and catching up with developed countries. Within these countries, there is often also a technological divide between people living in urban and those in rural areas, between women and men, and between the rich and the poor.

New technologies create new opportunities for many developing countries

New technologies create new opportunities for many developing countries. Renewable energy technologies and efficient energy storage systems can widen the scope for technological "leapfrogging". With the right infrastructures and institutional frameworks, biotechnologies can greatly improve health and nutrition. As discussed in earlier chapters, the use of AI can support a more efficient production of goods and services in both the public and private sectors. Crowd-based firms such as Airbnb and Uber — taking advantage of breakthroughs in digital technology and algorithms — have benefited both service providers and users through more efficient information flows. To help overcome

many of the shortcomings associated with existing technological divides, new technologies can create opportunities for less developed countries if they have the necessary digital infrastructure and applications that are appropriate for smaller markets and different consumption patterns.

There is also the possibility that existing technological backwardness will further widen the technological divides because people in many developing countries may be less prepared to adopt and take advantage of new technologies. The widespread automation and reshoring of many manufacturing jobs, for example, may deepen unemployment and underemployment crises in many developing countries, putting millions of jobs at risk of becoming automated (McKinsey Global Institute, 2017b). The use of robots may erode the low labour cost "advantage" of many developing countries, stifling their industrialization and export and import potentials (Shum and others, 2016).

The next section examines the challenges faced by countries and regions marked by existing technological divides, and the barriers that those divides erect against the development and adoption of frontier technologies. The latter part of the chapter discusses the opportunities and challenges presented by these new technologies to less technologically advanced developing countries and proposes key strategies for seizing the opportunities and overcoming the challenges.

The 2030 Agenda for Sustainable Development makes a commitment to leave no one behind. This means that no country or country group should be left behind, as technological advances create new opportunities for economic growth and prosperity. Technologies — both existing and frontier technologies — present the best hope for bridging the development divide and achieving broad-based sustainable development outcomes in developing countries. Considerable policy intervention will be needed at national, regional and global levels to make sure that the new technologies do not widen the technological divide and leave many developing countries further behind.

Frontier technologies: a bridge too far?

A great technological and developmental divide prevents possible leapfrogging and deriving the benefits of frontier technologies

Many low-income developing countries are yet to take full advantage of technological advances of the past two centuries. Electricity is still beyond the reach of billions of poor people; modern agriculture — entailing the use of fertilizer, pesticides and mechanical power — has not reached millions of farmers in sub-Saharan Africa and South Asia; and clean water and safe sanitation are still luxuries. These are manifestations of a great technological and developmental divide which persists between developed and low-income developing countries.

Closing these development gaps is not only an imperative under the 2030 Agenda for Sustainable Development, but also an absolute prerequisite for many developing countries to exploit the promises of many frontier technologies and bridge the technological divide that limits their growth potentials. Lack of access to electricity, inadequate health and sanitation facilities, dysfunctional education systems, under-developed physical and digital infrastructures prevent the possibility of leapfrogging and taking full advantage of frontier technologies.

The section discusses why the development and adoption of basic technologies remain incomplete within specific regions and countries, focusing on institutional, economic and cultural barriers. It will also discuss how these entrench developmental gaps, which limit the opportunities for harnessing frontier technologies.

Access to electricity: the bedrock of sustainable development

Access to modern electricity is correlated with improved education and health, gender equality and economic growth

Achieving universal access to modern energy has become a foundational development goal. It is also reflected in SDG 7, which is to "[e]nsure access to affordable, reliable, sustainable and modern energy for all". Electricity—the form of modern energy as envisaged in the 2030 Agenda—is a catalyst for the achievement of many other SDGs, given its positive correlation with improved education and health, gender equality, economic growth and other sustainable development outcomes.

Lack of electricity stands in the way of safer and healthier cooking and heating, and hinders access to powered health centres and refrigerated medicines, light needed for study at night, and the power needed to run a business. Electricity is also a prerequisite for the use of computers, access to the Internet and enjoyment of the benefits of frontier technologies such as 3D printing, AI and various applications of biotechnology.

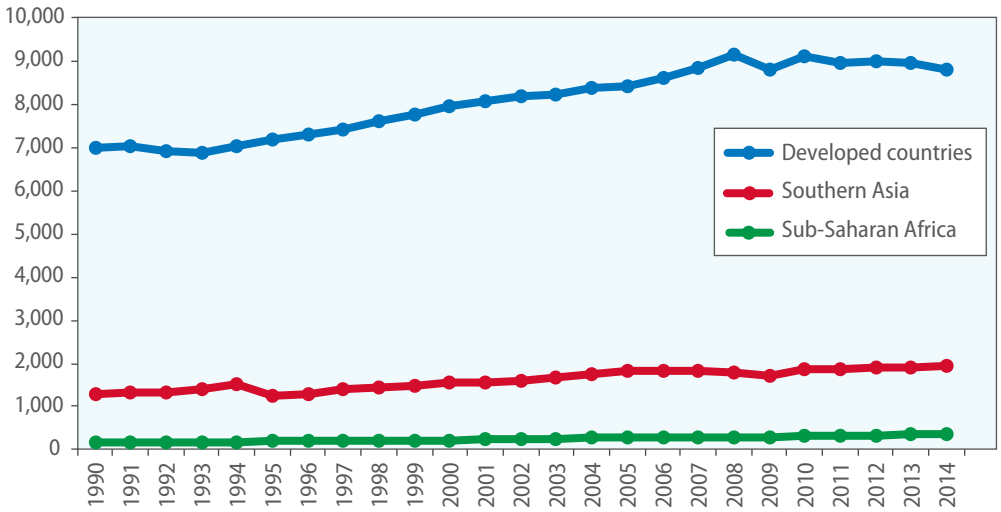
There has been notable progress in ensuring access to electricity in the new millennium. Over 100 million people per year have gained access to electricity since 2012 compared with an average of about 60 million per year in the period from 2000 to 2012. Despite this progress, 1.1 billion people were living without electricity in 2014, of whom 600 million lived in Africa. The proportion of people in sub-Saharan Africa with access to electricity was only 37 per cent.

In addition to low rates of access to electricity, the energy consumption per person in South Asia and sub-Saharan Africa remains very low. A typical refrigerator used in a developed-country household consumes about 500 kilowatt-hours (kWh) of electricity per year, which is greater than annual per capita energy consumption in sub-Saharan Africa. Further, per capita electric power consumption in sub-Saharan Africa has been stagnant since 1990 (see figure III.1 below), exposing a growing divide in energy consumption between developed and developing countries.

While supply-side factors generally explain the low access to electricity, new experimental research reveals demand-side constraints. Lee, Miguel and Wolfram (2016) estimated

Figure III.1

Annual electric power consumption per capita (kWh), developed countries, South Asia and sub-Saharan Africa, 1990–2014



Source: World Bank, World Development Indicators.

that consumer surplus from grid connections was far less than the total connection cost at all coverage levels. That is, many people are still not able or willing to pay for electricity.

Political economy processes have often led some Governments to prioritize supply-side considerations, instead of focusing on increasing affordability and willingness to pay for electricity. The lack of accountability mechanisms has often allowed electricity connections for certain interest groups, while ignoring the population groups needing electricity the most.

Remote areas can "leapfrog" the traditional electric connections and opt for off-grid solutions

The lack of electricity infrastructure in many remote areas presents an opportunity to introduce new types of electricity service. Remote areas could "leapfrog" the traditional electric connections and opt for off-grid solutions. Solar panels — a frontier renewable energy technology — are increasingly viable alternatives for millions in rural populations who cannot afford traditional electric connections. Technological advances and falling costs largely explain the growing demand for solar panels. New innovations integrating mobile money payments with home solar systems, such as the M-KOPA Solar in Kenya, have made it easier for households to adopt alternative energy solutions.

Utilization of solar power is clearly the most cost-efficient strategy for rapid electrification in sub-Saharan Africa (Aubin, 2018). The absence of traditional electrical infrastructure — an apparent sign of backwardness — is in fact an advantage for many developing countries to bypass on-grid electrification and adopt environmentally sustainable renewable enegy technology.

Water and sanitation: a prerequisite for human well-being

Access to clean water and hygienic sanitation is critical for good health and for the survival and development of children

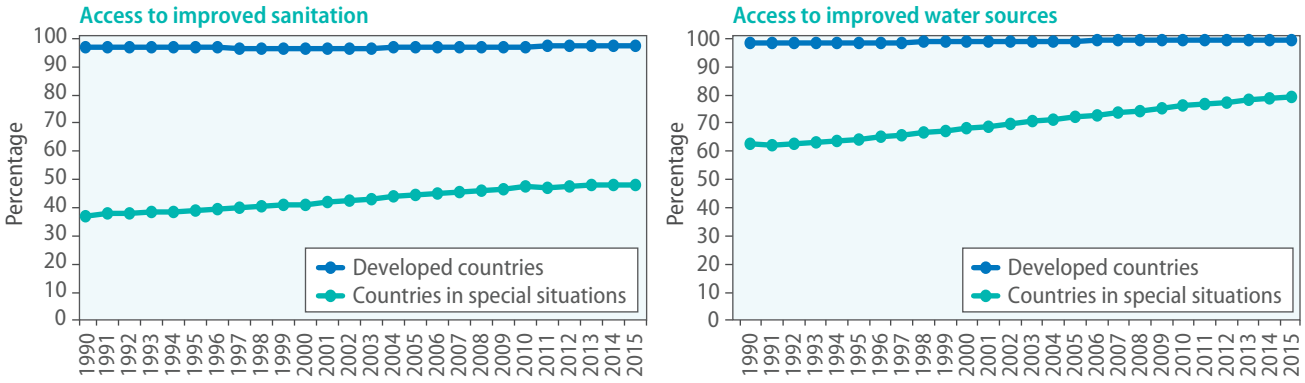
Access to clean water and hygienic sanitation is critical for good health in general and for the survival and development of children in particular. The lack of adequate basic sanitation facilities has serious implications for all dimensions of sustainable development. It results in sickness among children, stunting of their growth and diminishment of their cognitive abilities, all of which contribute to reduced productivity and income later in life. It is hard to imagine how the members of a population can be productive — continuously upgrading skills and taking advantage of many technological breakthroughs — without protecting their health through access to clean water and sanitation systems. In short, the lack of good sanitation affects public health, which in turn affects the ability of people to move up the technology ladder.

SDG 6 is to ensure availability and sustainable management of water and sanitation for all. While there has been noteworthy progress in these areas in recent decades, in countries in special situations, only 48 per cent of households had access to improved sanitation and 79 per cent to improved water sources in 2014 (see figure III.2 below).

The main impediments to access to adequate sanitation are poverty, lack of knowledge of its benefits, lack of access to sanitation supplies, absence of collective action, and the free-rider problem

There is disagreement, however, regarding the key reasons for the stubbornly high rates of inadequate sanitation. The main impediments are poverty, lack of knowledge of the benefits of improved sanitation, lack of access to markets where sanitation supplies can be purchased, absence of collective action, and the free-rider problem (Innovations for Poverty Action, 2011). While the focus of many countries has been on supplying access, often this has not been sufficient to solve the problem. There is therefore a need to further understand the dynamics of the demand side, including the contribution of social and cultural factors to discouraging or inhibiting adoption of upgraded sanitation practices. An

Figure III.2
Access to improved sanitation and water sources, developed countries and countries in special situations, 1990–2015



Source: World Bank, World Development Indicators.

integrated approach bringing demand- and supply-side interventions together can increase the possibility of increased adoption of sanitation technologies. New technology—in particular digital technology, ranging from mobile devices to social media—can play an important role in this respect.

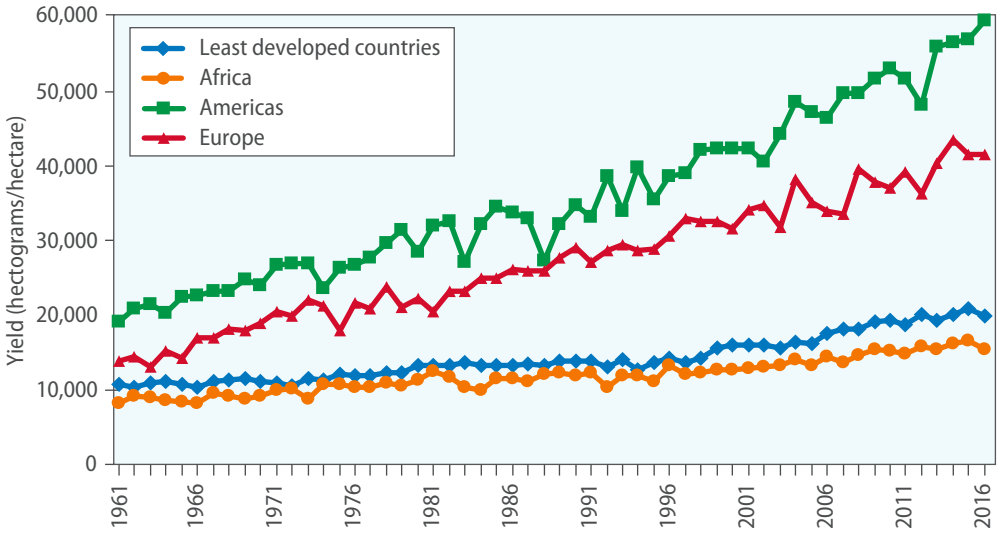
Low agricultural productivity: stumbling block to structural transformation

Low agricultural productivity limits the scope and pace of the structural transformation of many developing countries

The 2030 Agenda recognizes the importance of technology for enhancing agricultural productive capacity in developing countries, in particular the LDCs among them (see target 2.a). Broadly, target 2.3 of the SDGs is to double agricultural productivity. Both macroeconomic and microeconomic data suggest that differences in labour productivity between countries are larger in the agricultural sector than in other sectors, which is significant, as 56 per cent of people in LDCs work in the agricultural sector. Moreover, low productivity in the agricultural sector has impacts that extend beyond the agricultural sector, with regard, for example, to food security and improved nutrition of children. Low productivity prevents households and countries from accumulating assets, diversifying their economies and making use of new technologies to move into higher value added sectors. In short, low agricultural productivity limits the scope and pace of the structural transformation of many developing countries.

Since the early 1960s, the green revolution has facilitated the rapid transfer and adoption of new technologies in the agricultural sector, including use of fertilizer and pesticides, irrigation technology, mechanization of farms and new, high-yielding seeds. This enabled the shift in some developing regions from traditional to more modern agricultural methods. However, adoption of these technologies, such as fertilizer, were uneven across regions and countries. A sizeable number of countries missed out on the green revolution, and in consequence lagged in agricultural productivity and yields. The yields of sub-Saharan Africa and the LDCs have been stagnant since the 1960s and have risen—and only very slowly—since the late 1990s (see figure III.3).

Figure III.3
Total cereal yield, Africa, Americas, Europe and least developed countries, 1961–2016



Source: FAOSTAT.

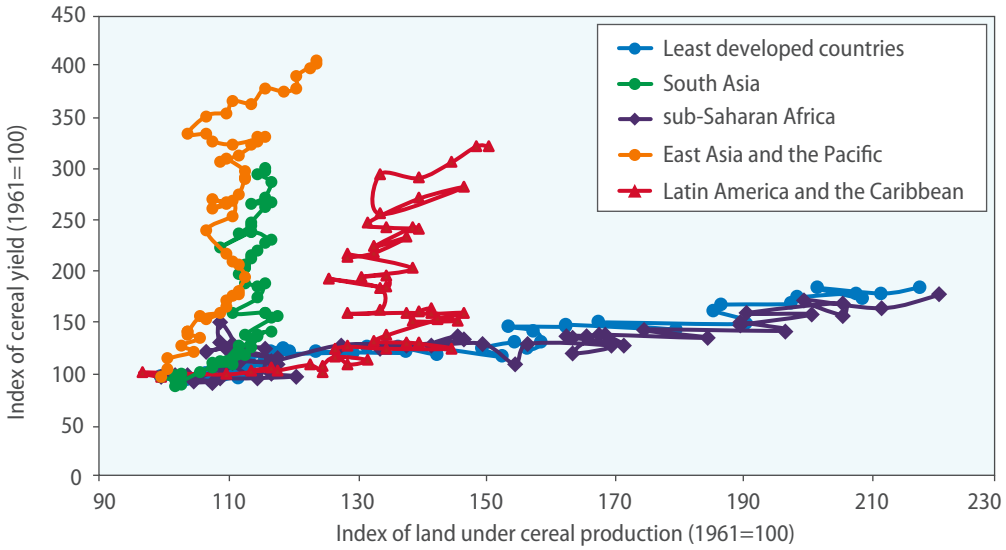
As a consequence of their failure to adopt new technologies, LDCs, including many countries in sub-Saharan Africa, have relied almost exclusively on expanding the area of land under cultivation in order to increase agricultural output, exacerbating deforestation and environmental sustainability. While the land area reserved for cereal production has more than doubled since 1961, yields have increased by only 80 per cent. This is in sharp contrast with South Asia, where land use for cereal production has increased by less than 20 per cent since 1961 but cereal yields have more than tripled (see figure III.4).

Studies have demonstrated that farmers often fail to perceive the potential gains to be reaped from new technology (Henna, Mullainathan and Schwartzstein, 2014). On the other hand, during the green revolution in India, social networks played a significant role in driving the adoption of various high-yield seeds (Munshi, 2004). Along the same lines, in Ghana, farmers who grow pineapple calibrate their use of fertilizer, observing and learning from the practices of others in their network (Conley and Udry, 2010). In many cases, raising awareness among peer farmers has proved more effective than programmes that focus only on information by extension agents from the government (BenYishay and Mobarak, 2014). In this respect, digital social media platforms can potentially further amplify the learning effect by sharing information and creating awareness of new farming techniques and technologies.

Policymaking needs to balance productivity enhancing objectives against their potential impact on labour demand since agriculture is the major source of livelihood and employment

New technologies can play a critically important role in improving agricultural productivity while at the same time reducing or maintaining land area used for agricultural purposes. Drones have the potential to scout crops and to reduce the hard work involved in seed planting and fertilization. Automated irrigation systems can enhance precision and reduce water use and manual labour. The gene-editing of seeds, although controversial, can increase resilience to disease, floods and drought (to be discussed further in the section on catching up with frontier technologies). At the same time, policymaking will need to balance such productivity-enhancing objectives against their potential impact on labour demand and livelihoods, as agriculture is the major source of livelihoods and employment in many developing countries.

Figure III.4
Size of increase in cereal yield relative to increase in land area reserved for production, various regions and least developed countries, 1961–2014



Source: UN/DESA, based on data from https://ourworldindata.org/grapher/change-of-cereal-yield-vs-land-used.

Education: the ladder to future prosperity

Although there has been remarkable progress at the primary education, the gap in secondary and tertiary education has remained wide in countries in special situations compared with developed countries

SDG 4 is to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. In recent decades, there have been remarkable improvements in school enrolment rates, which have boosted youth literacy rates. For example, there has been remarkable progress in countries in special situations, especially in the LDCs, where adult literacy rates grew from 45 per cent in 1990 to 58 per cent in 2016. Nonetheless, the gap in the gross enrolment ratio for tertiary education with respect to developed countries has remained wide. For example, SIDS, the best performers among the countries in special situations, averaged only 24 per cent in 2016 compared with developed countries which have experienced steady growth since 1990 (see figure III.5).

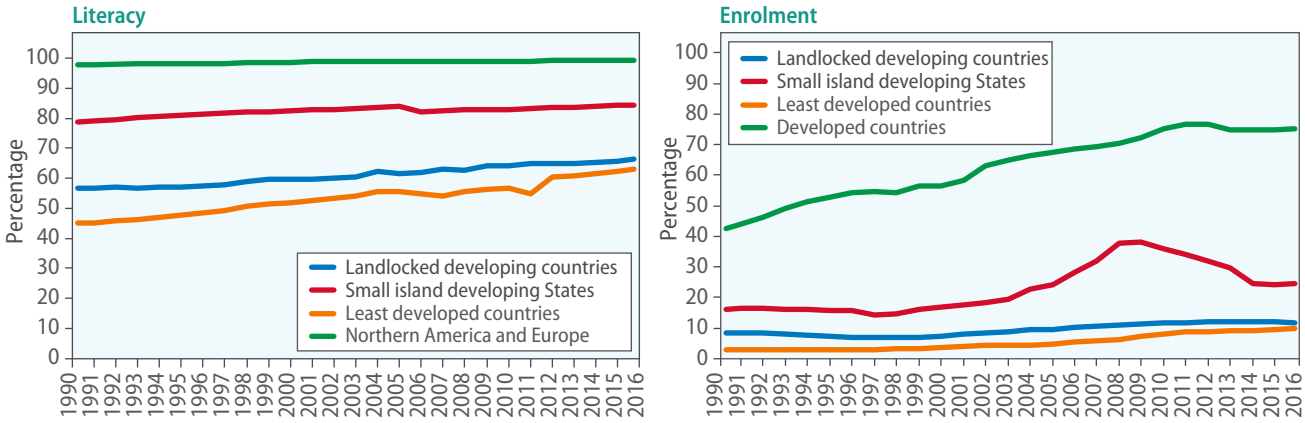
Similarly, despite considerable gains in school enrolment and literacy over the past decades, the lack of trained teachers and the poor condition of schools are undermining prospects for a high-quality education. In LDCs, only 58 per cent of primary education teachers and 68 per cent of secondary education teachers have the required training. In addition to the lack of qualified teachers, schools often lack basic infrastructure. In sub-Saharan Africa, for example, only about one quarter of schools have electricity and less than half have access to basic drinking water (United Nations, 2017c).

Reaping the benefits of technological innovation and strengthening domestic capabilities for research require improvement in the quality of schooling

In addition to literacy and numeracy, digital literacy is obviously an essential skill in the digital era. This explains why SDG target 4.4 focuses on substantially increasing "the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship". Less technologically advanced developing countries will need to improve their secondary and tertiary enrolment rates to increase the opportunities of their population for decent work in a knowledge-driven digital economy.

Low-quality education limits opportunities to both adopt technologies and develop domestic capacities for research, which is essential for replicating and improvising new

Figure III.5
Adult literacy rate, population 15+ years, both sexes; and gross enrolment ratio for tertiary education, both sexes, 1990–2016



Source: UIS.Stat.

technologies, so as to make them relevant for developing-country contexts. Although many countries have been able to catch up in terms of the number of years of schooling, their capabilities in adopting new technologies and initiating a catch-up process remain limited. Reaping the benefits of technological innovation and strengthening domestic capabilities for research in these countries thus require improvement in the quality of schooling—which remains a challenge that must be surmounted (see discussion in chap. IV).

Evidence related to skill-based technological change in developing countries (see, for example, Berman and Machin, 2000; and Conte and Vivarelli, 2011) stresses the importance of equipping students with the necessary engineering and scientific skills. Massive open online courses (MOOCs) can be helpful in transmitting knowledge in general and facilitating acquisition of new skills. These courses have the advantage of being scalable and customizable to the demands of individual students (Brynjolfsson and McAfee, 2011). For example, one such online course, on AI, offered at Stanford University (Palo Alto, California) in 2010, attracted more than 58,000 students worldwide. Lectures have been broadcast online and student progress is tracked through an automated grading system. This approach enables students around the world to follow a state-of-the-art course on AI at a very low cost, while also enabling the instructors to increase their productivity (Haider, 2018).

MOOCs could potentially help to further develop human capital and promote lifelong learning opportunities. However, if full advantage is to be taken of this technology for all, a basic educational and technological infrastructure must first be put in place. Challenges to be confronted in this regard include underdeveloped information and communications technologies (ICT) infrastructure, the high cost of broadband Internet connections, limits to the availability and capacity of instructors to deliver online lectures, and the limited exposure of students to online learning platforms. Access to broadband Internet connections is still very limited in many developing countries. Many of those countries are struggling to provide electricity connections in rural areas, which makes providing educational opportunities entailing the use of new technologies quite challenging. In many countries in sub-Saharan Africa, the proportion of schools with access to computers and the Internet for pedagogic purposes is below 40 per cent (United Nations, 2017c).

Mobile phones and the Internet: connections to the future

Increased mobile coverage has contributed to a steady increase in the number of Internet users

The 2030 Agenda for Sustainable Development recognizes explicitly the potential of ICT to facilitate global interconnectedness and to accelerate human development. In the last decade, mobile cellular services have spread at a rapid pace. While fixed-broadband services remain inaccessible across large sections of the developing world, increased mobile coverage has contributed to a steady increase in the number of Internet users in all regions.

Access to mobile cellular phones has increased rapidly in both developed countries and countries in special situations, although a wide digital divide remains. In developed countries, the number of mobile cellular subscriptions per 100 people was 121 in 2016, compared with 78 per 100 people in countries in special situations. In the same year, in developed countries, 84 per cent of the population used the Internet, compared with 26 per cent in countries in special situations (see figure III.6 below). And while fixed-broadband penetration reached 30 per cent in developed countries, only 0.9 per cent had similar access in countries in special situations.

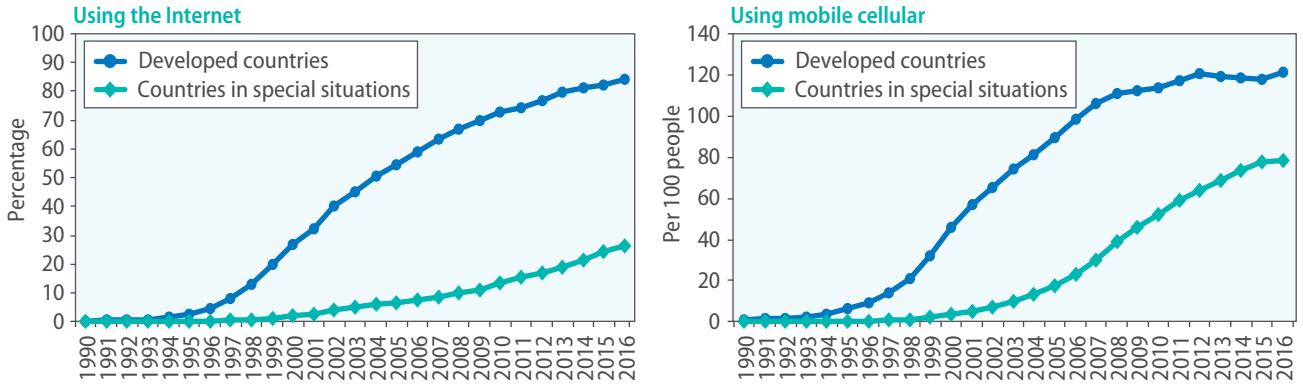
Effective use of the Internet is a function of digital literacy

While the Internet has reached many countries quickly, the intensity of use is lower in less technologically advanced developing countries, owing partly to a large within-country digital divide in many of those countries. For example, there are important gaps in access to Internet between men and women, urban and rural areas, and the young and old (see figure III.7). One explanation for the between- and within-country divides is that effective use of the Internet is a function of literacy. Hence, closing the digital divide points to the need to focus on basic and secondary education and digital literacy.

The mobile revolution has given hope to many poor and vulnerable countries that they, too, can become dynamic and innovative players in the digital economy. Mobile phones have connected people not only with other people but also with a realm of undreamt possibilities. For example, in countries of sub-Saharan Africa, M-Pesa has been an inspirational example of what could be accomplished in certain sectors. Further, mobile phones have also contributed to improving the efficiency of agricultural markets (Aker and Fafchamps, 2015), boosting educational outcomes (Aker, Ksoll and Lybbert, 2012) and

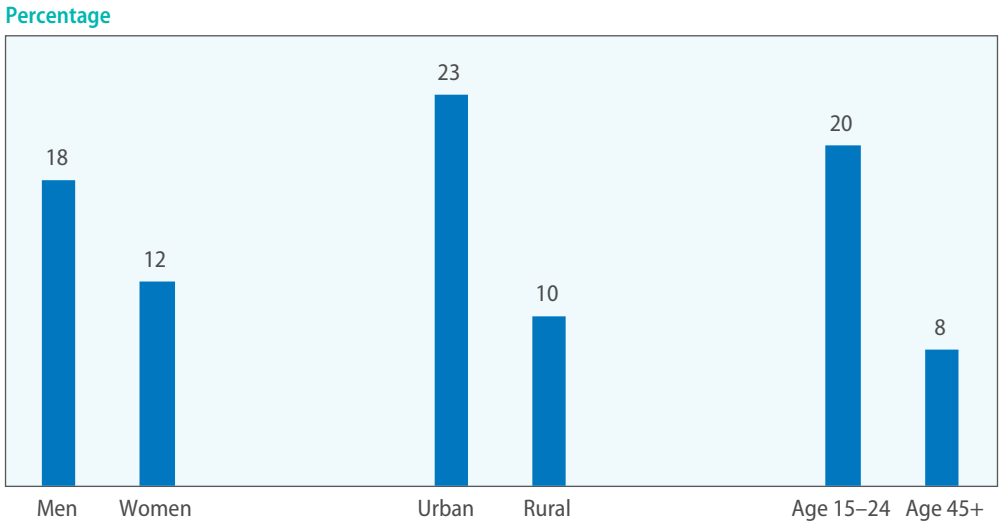
Figure III.6

Access to the Internet and usage of mobile cellular phones, developed countries and countries in special situations, 1990–2016



Source: World Bank, World Develoment Indicators.

Figure III.7
Individuals with access to Internet in Africa, by demographic group, 2016



Source: World Bank (2016).

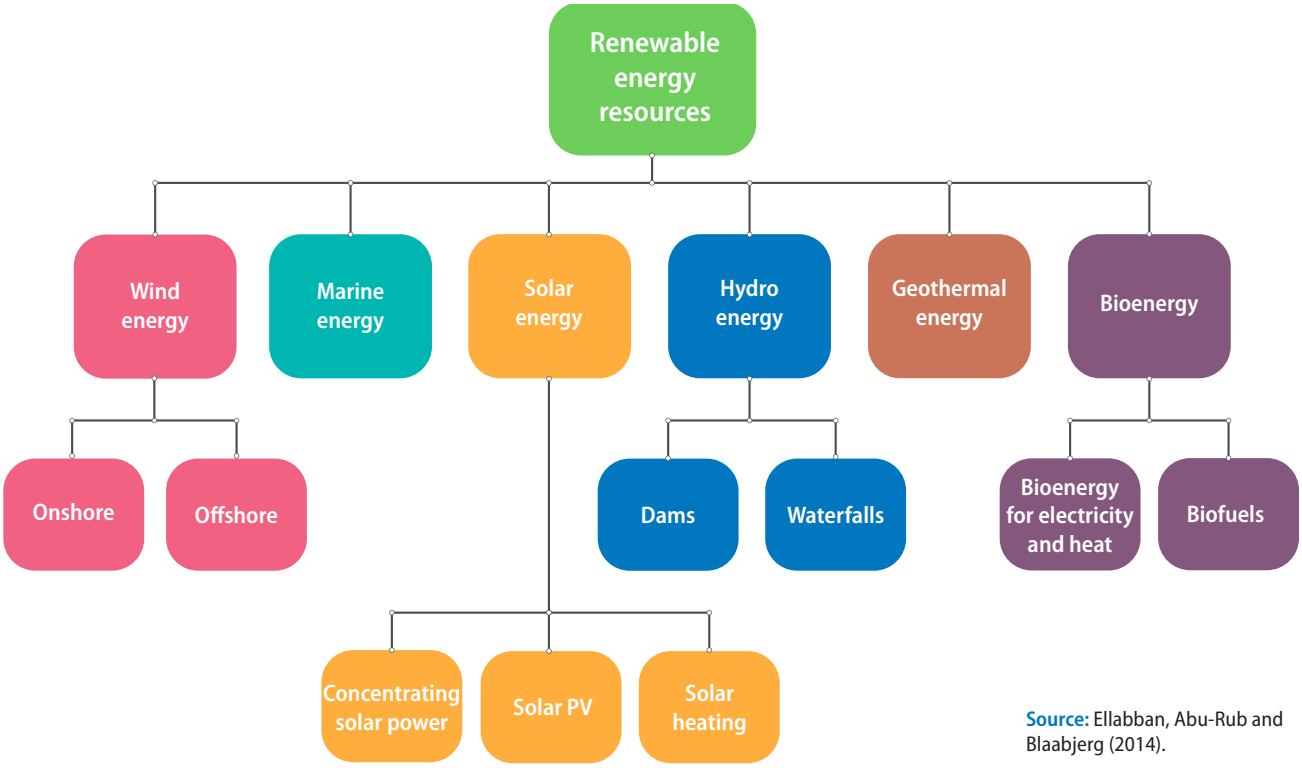
even reducing poverty (Suri and Jack, 2016). However, while mobile phones have spread rapidly, investment in complementary infrastructure such as electricity and cellular stations has not occurred at the same speed. As a result, people in many of these countries still must traverse long distances to charge their phone or receive a signal. Moreover, while the mobile revolution offers useful services for consumers, it has not succeeded in creating a larger number of formal jobs, establishing basic infrastructure for economic development or for attracting other related technologies (Schwab and Davis, 2018). The majority of developing countries must overcome the persistent digital divide if they are to tap the potential of many frontier technologies and step into a sustainable future.

Catching up with frontier technologies

Renewable energy technologies: the best hope for achieving environmental sustainability

Renewable energy technologies (RETs), which use wind, ocean, solar, hydro, geothermal and bioenergy sources, possess the collective potential to generate massive amounts of energy—over 3,000 times the current global energy needed (Ellabban, Abu-Rub and Blaabjerg, 2014). Figure III.8 provides an overview of the various types of renewable energy resources, displaying the forms that they may take. RETs convert these natural energy sources into usable forms of energy such as electricity, heat and fuels. Globally, 20 per cent of total electricity generation is provided by renewable energy, which supplies 10 per cent of the heat demand and 2 per cent of the biofuels. Notably, in 2017, more than half of all newly installed generating capacity worldwide was in the form of renewable energy. The share of renewable energy is expected to rise further, as unit costs of photovoltaic (PV) and other renewable sources will continue to fall (International Energy Agency, 2018a).

Figure III.8
Overview of renewable energy technologies



Source: Ellabban, Abu-Rub and Blaabjerg (2014).

Development and adoption of renewable energy technologies

Use of RETs enables reduction of GHG emissions, improvement of watersheds, access to clean energy and green employment opportunities

In general, the use of RETs enables the reduction of greenhouse gas (GHG) emissions, the improvement of watersheds, access to clean energy and green employment opportunities. Shifting to renewable resource-based power generation also maximizes the beneficial impact of electric vehicles on the environment. The use of RETs can foster sustainable development through (a) appropriate resource management, (b) economic sustainability through infrastructure and service development for provision of affordable renewable energy to rural populations, (c) social sustainability by improving the welfare of the poor and supporting women's income generating capacities and (d) financial sustainability by ensuring programme implementation of RETs in the short and medium term (Bugaje, 2006).

Renewable resources are yet to be fully exploited in sub-Saharan countries. Currently, renewable power generation capacity is 28 gigawatts (GWh) compared with a total power generation capacity of more than 145 GWh.[1] Hydropower accounts for more than 90 per cent of total renewable energy capacity in Africa. Data for 27 African countries that report to the International Energy Agency (IEA) indicate that wind is abundant in West and East Africa, hydro and biomass are abundant in Central Africa, and solar energy is available in all regions. Each source of renewable energy can potentially supply the total African electricity demand; solar energy, for example, could provide more than 2,000 per cent of the total electricity for final consumption in 27 African countries (see table III.1).

1 One gigawatt-hour (GWh)=1 billion (10^9) watts/hours which can supply energy to a medium-sized city.

Table III.1
Electricity generation potential from renewable energy as a percentage of total final consumption of electricity

	Wind	Solar	Hydro	Biomass	Geothermal
Northern	449	898	35	114	-
Central	688	5 245	6 059	9 011	-
East	3 240	8 875	1 298	1 441	198
West	1 096	3 520	292	178	-
Southern	416	1 527	13	47	-
Africa IEA[a]	**724**	**2 136**	**349**	**498**	**17**

Source: Mandelli and others (2014).

a Covering 27 African countries that report their data to the International Energy Agency (IEA).

There are renewable energy projects that have had sizable impacts on local and regional economies, including on the generation of employment. For example, RETs—in the form of solar energy and wind energy—have proved a viable energy source in Northern Africa. Vidican Auktor (2017) has reviewed the development of renewable energy—based on solar, wind, and hydro energy—in Morocco as a green industrial policy. Morocco started to experiment with renewable energy in 1996 with the introduction of the Programme d'Électrification Rurale Globale (PERG). The programme, which proved highly successful, increased rural electrification to 98 per cent in 2010, up from only 15 per cent in 1996 (Haider, 2018).

The employment impact of PERG was also significant, with about 13,000 direct and indirect jobs having been created by the Programme by 2006. The positive experience of renewable energy in Morocco also led to the launch of the National Renewable Energy and Efficiency Plan in 2008 with the aim of harmonizing different renewable energy strategies (ibid.).

There is potential for further development of RETs in Caribbean countries based on the abundance of renewable energy resources

RETs also contribute to energy generation in a few Caribbean countries such as Grenada (photovoltaic), Barbados (solar water heating), Jamaica (wind) and Suriname (wind). The use of clean energy has been cost-effective in the face of volatile oil markets and has promoted reliance on local resources, reduced GHG emissions and generated green jobs. There is also potential for further development of RETs in the region, based on their abundance of renewable energy resources (Shirley and Kammen, 2013). For example, under the National Energy Policy of Grenada, it is projected that 20 per cent of energy consumption in the stationary power and transportation sectors will be met with renewable energy by 2020; waste to energy from biomass and municipal solid waste hold great potential, although infrastructure for these systems is not yet in place. Distributed generation in the form of solar PV and solar water heating already have applications for the water treatment and distribution and ecotourism sectors. Policies that currently encourage distributed solar technologies would also increase the resilience of the Grenada grids to storms and other disasters (United Nations, 2012).

Broadly, although the primary energy supply for power generation and final consumption in many SIDS (mostly for transportation and industry) is based on imported oil,

a few countries have sizable shares of renewable energy sources in total electricity generation (hydropower in most cases), including Fiji (54 per cent), Belize (53 per cent), Suriname (46 per cent), Dominica (40 per cent) and Papua New Guinea (39 per cent). Tokelau (a Non-Self-Governing Territory administered by New Zealand) has become 100 per cent solar PV (Timilsina and Shah, 2016).

A study of a wide group of political jurisdictions (34) in the Caribbean was conducted on the role of institutional factors (entrepreneurship, local champions, electricity utility, informal institutions and international agencies) in the adoption and development of RETs. It was found that informal elements, such as historical legacy, cultural norms and degree of stakeholder interactions can be as important as formal institutions and policy structures (e.g., tax schemes, economic incentives and subsidies) in promoting the adoption and development of those technologies (Ince, Vredenburg and Liu, 2016).

In Viet Nam, where nearly 2 million households live in sparsely settled, remote rural areas, stand-alone household-size RETs, such as solar PV and wind generators, have been proposed as offering a good solution to the problem of the high cost of grid extension. As decentralized RETs can be located closer to demand, distribution and transmission costs and energy and capacity losses would be reduced. RETs can also create local employment since installation, operation and maintenance would be conducted mainly in rural areas (Nguyen, 2007). Further, a study by Sen and Bhattacharyya (2014), centred on Palari, a remote village in the State of Chhattisgarh (India), suggests that a hybrid combination of RETs at an off-grid location (e.g., wind turbines, solar PV systems, biodiesel generators and small-scale hydropower) could generate electricity and serve as a cost-effective alternative to conventional grid extension.

In the Philippines, a pilot project has been developed to allow rural communities to access affordable solar energy and ICT. For example, the Leapfrogging Autonomous Micro-Technopolis in Boxes (LAMTIB) initiative, for which the Renewable Energy Corporation (REC) SolarBox is the driving technology, is a pilot development project designed to enable rural communities in off-grid areas to access affordable solar energy and ICT (Aunemo, 2015). The project, which is in its initial stages of implementation aims at strengthening connectivity, food security, education, health care and small-scale business. Via satellite, the local community can gain access to information and means of communication, including remote control engineering of the solar panel installations. The project also includes a process for cultivating larvae for use in a sea farm located in the Santa Cruz barangay.[2] Immediate access to the larvae, whose production and monitoring are made possible by solar electricity from the SolarBox, eliminates long travel distances, thereby increasing their survival rate. Another goal of the project is to raise awareness through use of online education systems run by solar electricity. Local communities are also provided with medical expertise and a telemedicine system, operated by the Philippine Red Cross. The sea farm in Santa Cruz has begun to generate economic activity in the community by sourcing untapped raw materials locally and integrating them with various new activities so as to facilitate sustainable growth. Local businesses are expected to expand through the use of solar energy and Internet connectivity, as a means of gaining key information on production and markets.

2 A barangay is the smallest administrative division in the Philippines, constituting the most local level of government.

Recent developments in battery technologies have made RETs in off-grid locations more viable options for many communities in Asia and beyond

Recent developments in battery technologies have made RETs in off-grid locations more viable options for many communities in Asia and beyond. New energy storage technology is crucial in RET-based mini- and off-grid systems as the means of handling moment-to-moment fluctuations in production or consumption (Eller and Gauntlett, 2017). In the case of mini-grids: battery systems are installed for backup to ensure a stable flow of power; and both solar PV systems and batteries are built independently from the centralized grid (IEA, 2018a). Mini-grids with energy storage systems are a cost-effective and time-saving option for isolated communities as regards meeting SDG 7, which is to ensure "access to affordable, reliable, sustainable and modern energy for all".

As storing energy is particularly important for intermittent power plants, such as renewable electricity sources, it can play a significant role in meeting the need for low-carbon electricity in many developing countries. Among several types of batteries for stationary storage, the lithium-ion battery is considered most promising, as the capacity of lithium-ion battery storage has been improving and its costs declining, owing to the development of electrical vehicles (EVs) (see chap. II). This battery is becoming a popular option for battery-based renewable systems (Diouf and Pode, 2015).

In this context, EVs in many countries have become the quintessential symbol of rapid growth in the renewable energy industry, including in the use of RETs. While they provide opportunities for clean energy transportation, their continued development presents challenges in connection, for example, with their energy storage capacity. Renewable energy policies have been directed not only towards reduction of carbon dioxide emissions but also towards the creation of local environmental and health benefits; facilitation of energy access, particularly in rural areas; advancement of energy security goals through diversification of the portfolio of energy technologies and resources; and improvement of social and economic development through employment opportunities (Ellabban, Abu-Rub and Blaabjerg, 2014). Table III.2 illustrates the likely positive impacts that the deployment of RETs may exert on three dimensions of sustainable development, i.e., social development, environmental protection and economic development.

Challenges and strategies

Fossil fuels could continue to be the primary source of energy in many developing countries if policy incentives and long-term commitment are not in place

Although the use of renewable energy resources is rising, fossil fuels still account for 80 per cent of the world's energy supply. It is likely that fossil fuels could continue to be the primary source of energy in many developing countries if policy incentives and long-term commitment are not in place.

The share of electricity generation based on RETs is nearly 20 per cent in LDCs, landlocked developing countries and small island developing States as a whole, which indicates that the potential of renewable energy use is still untapped. While hydropower and bioenergy are major sources of energy worldwide, other sources, although technically feasible and commercially available, cover only a fraction of their potential markets (ibid.).

Deployment of RETs is confronting various socio-economic, institutional, technical and environmental challenges. Economic barriers persist when the cost of a given RET is above the cost of competing alternatives; market-related and technical barriers are also important determinants of the cost and use of RETs. Economic, market and technical barriers contribute to higher capital costs and prevent the development and adoption of RETs. The significance of barriers differs for each technology and market, while affordability and willingness to adopt change as a technology matures along the path towards commercialization.

Table III.2
Positive impacts of RETs on sustainable development

	Outcome		
Input	**Social**	**Environmental**	**Economic**
Social	Local ownership and decision-making Community building	Improvement of environment-friendly behaviour Higher quality of life	Building of community assets Regional development Improved income diversification and distribution Employment
Environmental		Reduction of GHG emissions	Renewable energy industry Higher-quality growth
Economic			Enhancement of shareholder income and community income

Source: UN/DESA.

A comprehensive study of Caribbean countries has demonstrated that the development of a renewable energy industry progressed when the incumbent electric utility wielded less influence in setting policies for the development of RETs. This reflects a classic conflict of interests, the case where incumbent utilities often have little incentive to welcome a new source of energy, which would replace traditional sources. It is not surprising, then, that utility companies typically promote business models that do not support renewable technologies. On the other hand, the involvement of the electric utility is often essential to facilitating and sustaining the renewable energy sector since it has acquired local experience (Ince, Vredenburg and Liu, 2016) and amassed the capital investments required for renewable energy projects.

Small island developing States face major barriers to the development and use of RETs

Small island developing States, including those in the Caribbean, face four major barriers to the development and use of RETs: an inadequate energy information network and lack of awareness of the benefits of renewable energy technologies; poor financing mechanisms through which to implement renewable energy projects, including regional loan structures and technical assistance for banks; weak or non-existent regulatory frameworks to enable renewable energy development; and inadequate technical capacity in the renewable energy field (Wiesser, 2004).

Broadly speaking, energy policies and planning guidelines in developing countries are important to ensure that there is a proper evaluation of RET potential—one that is not impacted by the vested interests of public utilities or electricity boards which may prioritize traditional high-carbon energy technologies (ibid.).

Deployment of RETs for electrification in rural areas entails high upfront equipment costs, high costs for transmission and distribution, a high dependence on external resources and institutional support

In remote rural areas, deployment of RETs for electrification often entails high upfront equipment costs, high costs for transmission and distribution, a high dependence on

external resources and institutional support. Economic barriers include a high initial capital cost, failure to estimate future risks related to fossil fuel, and lack of pricing policies that include the economic costs of environmental damage, as well as the lack of an appropriate level of subsidies for incentivizing RET use at household levels. Legal and regulatory barriers include legal frameworks that discourage investment in RETs and excessive requirements for small power producers. The lack both of access to credit for consumers and investors and of the technical, geographical and commercial capacities needed by market participants to take economic decisions (Urmee, Harries and Schlapfer, 2009) also inhibits the potential of RET deployment and use.

In their study of Malawi (with regard to efficient stoves and efficient tobacco barns), Rwanda (with regard to household and institutional biogas) and the United Republic of Tanzania (with regard to solar energy, domestic biogas, efficient stoves and efficient ovens), Barry, Steyn and Brent (2011) pinpointed four main types of factors that should be taken into account for the selection of a particular RET:

(a) Technology factors, including maintenance and support over the life cycle of the technology and transfer of knowledge and skills to relevant people;

(b) Site selection factors, including identification of a local champion to enable continuation after implementation, adoption by the community and identification of suitable sites for pilot studies;

(c) Potential income generation and costs, including initial installation costs; and,

(d) Management and technological capacities.

In the countries under study, these factors often became barriers to the adoption and development of RETs owing to an insufficient number of skilled personnel, weak institutional capacities to implement effective environmental policies, lack of knowledge of the advantages and opportunities presented by RETs, lack of the training and knowledge transfer needed to support the maintenance of the technology, and lack of community education programmes designed to reduce user reluctance to accept the technology. At the same time, international cooperation can make a significant difference in these areas through support of actions by countries to strengthen institutional and innovation capacities across sectors.

A study by Ahlborg and Hammar (2014) on Mozambique and the United Republic of Tanzania indicates that the use of hydropower for off-grid electrification in remote rural areas can be a good complement of and forerunner to the national grid, while at the same time underlining the barriers to implementation. For example, opposition to the exploitation of protected areas, as well as seasonal droughts and high planning costs for small-scale hydro, reduce the use of hydropower. Moreover, interest in wind power is low due to expected high costs and energy fluctuations. Solar PV is used in both countries but not on a wide scale because it is both expensive and unsuitable for productive use due to low capacity.

Policies for making renewable energy technologies the main energy source

The challenges associated with RET development and deployment underscore the need to develop well-designed strategies along three main axes: (a) increasing complementary investments in sectors beyond energy generation so as to maximize social, environmental and economic impacts of RETs; (b) strengthening a nation's institutional framework to facilitate the deployment of RETs and; (c) designing national and sectoral policies aimed

at integrating the renewable energy sector into the framework of a comprehensive national energy plan that is within the scope of a national development strategy.

There is a clear need for the deployment of RETs to be integrated with, and complemented by, investments in other sectors, such as infrastructure, social services, local finance, education and rural development. The government needs to invest in its administrative capacity to engage in systematic and timely communication with local communities so as to facilitate the use of RETs, provide subsidies to reduce capital costs and facilitate market development. The chosen RET must reflect the priorities of local populations, taking into account their capacity and willingness to pay. There is also a clear need for more effective communication and awareness building regarding the costs associated with the use of RETs. Renewable energy projects should demonstrate how RETs can improve livelihoods through, for example, job creation in rural communities.

The deployment of RETs needs to be integrated with, and complemented by, investments in infrastructure, social services, local finance, education and rural development

There should also be concerted efforts at local levels to expand access to credit and financing opportunities in order to facilitate the development and adoption of RETs. Governments should consider lowering import tariffs and taxes for imported components of RETs, as well as support greater investment in research and development (R&D) to render RETs more commercially viable for poorer segments of the population. National innovation systems can play an important role in identifying and developing specific RETs, while at the same time taking into account country- and region-specific opportunities and challenges.

For SIDS in particular, any public incentive would have to be attractive enough to make renewable energy sources competitive against other sources of energy in the small-sized markets of these countries. Fiscal incentives such as feed-in tariffs, tax incentives and production subsidies may be needed for the effective adoption and development of RETs.

Government participation in, and support for, developing necessary institutional frameworks will remain critical for the adoption and development of RETs. In this sense, the 2030 Agenda for Sustainable Development and the Paris Agreement adopted under the United Nations Framework Convention on Climate Change[3] are key institutional pillars of the process of bringing together all nations for the purpose of ensuring that economic, social and technological progress occurs in harmony with nature. There also needs to be clear and unequivocal policy signals, prioritizing renewables within the energy policy and the national energy matrix. Government interventions are also needed to establish standards and codes of practice and to integrate renewable energy development with environmental policies and energy efficiency. Building national capacities for RET, including the training of personnel, will remain key for facilitating further development and use of renewable energy.

The reform and strengthening of institutional frameworks is needed to enable adoption and development of new technologies to become a flexible, collaborative and integrative enterprise at the local, national and international levels. Adequate cross-sectoral and international collaboration could ensure proper cooperation between the energy sector and other sectors such as agriculture, environment and forestry.

Strengthening of institutional frameworks is needed for a flexible, collaborative and integrative development of new technologies at the local, national and international levels

There is also strong evidence that the countries that have successfully promoted RETs combined their long-term development strategies with concrete policies and measures designed to support their aspirations, including effective management and the setting up of government structures for the implementation of renewable energy projects. National

3 See Adoption of the Paris Agreement in United Nations Framework Convention on Climate Change (2015).

development strategies should prioritize RETs and incorporate specific incentives — including subsidies for R&D — to encourage private sector participation in development, generation and transmission of renewable energy.

Biotechnologies: eradicating hunger and achieving good health are within reach

Advances in biotechnology, precision farming and production ecology can unlock the capacity to carry out structural transformation and bridge the development divide with developed countries

Agriculture faces global challenges which include meeting the growing demand for food, reducing poverty and malnutrition, and achieving environmental sustainability. However, the yield growth rates reached with conventional plant breeding and agronomic practices have on average declined as a result of soil erosion and low productivity. As discussed above, stunted agricultural labour productivity in many developing countries, particularly in sub-Saharan Africa, makes structural transformation of their economies a daunting challenge. Advances in biotechnology, precision farming and production ecology offer hope for a significant boosting of crop yields and agricultural productivity, with the potential for unlocking the capacity to carry out structural transformation and bridge the development divide with developed countries. This will remain critical for achieving many SDGs, including eradication of extreme poverty and hunger.

Biotechnologies can improve living standards in countries in special situations, increasing food output and nutritional quality and improving the health status of their population. Genetic bio-fortification of food crops can be economically and biologically effective in reducing micronutrient deficiencies and alleviate malnutrition through, for example, the nutritional enhancement of vitamin A-fortified rice (FAO, 2011). Maize can also be an appropriate crop for bio-fortification, since many people, e.g., in sub-Saharan Africa, consume maize at most of their meals. Recombinant protein targeting of seeds and the use of high-volume food-processing technologies (e.g., freeze-drying) can reduce the need for a "cold chain" between the point of production and the point of delivery (Ma and others, 2005). However, adoption of new crop varieties and related agricultural technologies often face cultural barriers in traditional agrarian societies, with lack of knowledge and awareness of their benefits and costs. Effecting bio-fortification of crops may therefore require not only extension services for seed distribution, but also mass awareness campaigns for farmers and community members, focused on informing how new crop varieties will improve their health and well-being. That genetic modification of crops holds out hope for eradicating hunger doesn't mean that poor farmers shouldn't be fully informed of both the benefits and the risks so that they can make an informed decision.

The tool of gene adaptation for development of insect-resistent crop varieties can be utilized by smallholders to reduce their exposure to the risks of pest damage and yield loss, without being required to introduce chemicals. Growth of insect-resistant cotton in a number of developing countries attests the successful application of this technology in generating higher productivity and higher farmer incomes, while ensuring equity and sustainability (Raney, 2006). Transgenic crop alternatives are being developed that display resilience to hazards such as drought, freezing, salinity, and soil toxins such as aluminium and heavy metals. Crops bearing those traits require less irrigation and provide more reliable yields (Tonukari and Omotor, 2010). Along similar lines, improved herbicide tolerance of crops can augment the incomes of poor farmers by increasing crop yields and reduce the amount of time needed to clear weeds.

Effective development and adoption of biotechnology in less advanced developing countries can also impact health in a positive way if new products and technology were to become affordable and adjustable to health-care settings, as well as socially and culturally acceptable, while addressing the most pressing health needs. Table III.3 below illustrates a few of the biotechnologies that are potentially important for many developing countries.

Table III.3
Relevant biotechnologies

1	Modified molecular technologies for simple and affordable diagnosis of infectious diseases
2	Recombinant technologies for development of vaccines against infectious diseases
3	Sequencing of pathogen genomes for the purpose of building an understanding of their biology and identifying new antimicrobials
4	Female-controlled protection against sexually transmitted diseases, both with and without contraceptive effect
5	Bioinformatics for identifying drug targets and examining pathogen-host interactions
6	Genetically modified crops with added nutrients for countering specific deficiencies
7	Recombinant technology for making therapeutic products (e.g., insulin, interferons) more affordable
8	Combinatorial chemistry for drug discovery

Source: UN/DESA, based on Daar and others (2007).

Advances in biotechnologies can directly contribute to improving health outcomes for millions of poor people in developing countries

Advances in biotechnologies can also directly contribute to improving health outcomes for millions of poor people in developing countries. They can support a more accurate diagnosis to spur prompt treatment, limit the spread of disease and prevent waste of resources on wrong treatments. Some recombinant vaccines for malaria and hepatitis, imported at a fraction of the cost for standard imported medicines, have been tested in a number of poor countries with promising results. The technology for more efficient drug and vaccine delivery systems is also important because most vaccines are administered by injection, which can increase the risks of contamination and contagion as many blood-borne diseases such as HIV/AIDS and hepatitis B are transmitted through unsanitary injections. Frequent dosing of, for example, powdered and edible vaccines and controlled-release formulations can replace multiple doses; and refrigeration can ensure safety with respect, e.g., to possible environmental contamination, improving access to drugs and vaccines and potentially saving millions of lives. Recombinant therapeutic proteins are also relevant for developing countries, where 60 per cent of all deaths are due to non-communicable diseases—a figure that may grow up to 73 per cent by 2020. Biotechnologies for environmental improvement such as bioremediation can also help transform unhealthy pollutants in the soil or water and improve public health (Daar and others, 2007).

Similarly, plant-derived pharmaceuticals (PDPs) has a huge potential in terms of enabling low-cost drugs and vaccines to be supplied to developing countries. Making use of traditional knowledge on the capacity of some plants to reduce the effects of diseases, laboratory analysis can help identify the plant substances and agents that have healing capacities. Cultivating and experimenting with those agents to produce pharmaceuticals and vaccines present the opportunity to develop a uniquely innovative branch of the

pharmaceutical industry. PDPs can help transform the agricultural economies of developing countries and improve the health care and productivity of poor people. There is a great potential for the cost-effective production of molecules that can reduce the spread of infectious diseases, particularly HIV/AIDS. Local and regional production of PDPs can become more feasible when carried out in proximity to populations that need these pharmaceuticals.

Hunger and poverty are rooted in inequality, which would need to be addressed within a comprehensive and integrated approach to poverty reduction

Biotechnologies are not a panacea. The importance of proved health strategies such as health education are central to many health-related challenges, including combating HIV/AIDs and other epidemics. Similarly, improvements in sanitation can reduce the incidence of water-borne diseases, while basic nutritional education can help prevent nutrient deficiencies. Although biotechnologies can potentially help alleviate hunger, one should not forget that hunger and poverty are rooted in inequality, which would need to be addressed within a comprehensive and integrated approach to poverty reduction.

Joint research in epidemiology, nutrition and food toxicology is needed to select the traits and demonstrate the benefits of bio-fortified crops

Before drawing conclusions regarding how the simple availability of biotechnology may improve agricultural productivity and the health of the rural poor, it is important to keep in mind that trickle-down biotechnologies designed for large-scale farming would need to be reproduced and replicated in smaller farm contexts (Jansen and Gupta, 2009). Moreover, although genetic modification of crops can help support the design of foods with specific health protective properties, joint research in epidemiology, nutrition and food toxicology is needed to enable the selection of traits and demonstrate the benefits of bio-fortified crops in less technologically advanced developing countries (Azadi and Ho, 2010).

Mindful that African countries needed to tap the advances in biotechnology, delegates to the Extraordinary Conference of the African Ministerial Council on Science and Technology, held in Cairo in November 2006, analysed and discussed the report of the High-level Panel on Modern Biotechnology, entitled *Freedom to Innovate: Biotechnology in Africa's Development* (Juma and Serageldin, 2007). Its goal was to generate a critical mass of technology expertise in areas of potential growth and take advantage of Africa's rich biodiversity to develop pharmaceutical products. The report called for an African Biotechnology Strategy to promote this vision within 20 years. The initiative has so far collected vital information on medicinal plants and built pilot databases, while strengthening regional links for mutual collaboration on science and technology among universities, research centres and industry. The objective of the Federation of Asian Biotech Associations, another example of partnership between industry and academia, is to boost investment in biotechnology, international trade in biotechnology products, and the outsourcing of services (Gurib-Fakim and Eloff, 2013).

A survey of the recommendations of 232 developing-world experts from 58 countries was conducted to determine how to boost the potentials of biotechnology and improve public health in poor countries (Daar and others, 2007). The survey's results indicated that there is great potential for intersectoral, regional and international collaboration on building capacity as well as encouraging regions to learn from successful models of biotechnology innovation. They called for increased partnership and capacity-building to improve science education and establish support networks to improve dialogue between biotechnology developers and end users. Experts also underscored the importance of biotechnology as an instrument for improving public health as well as a tool for economic development. A few experts indicated the need to identify appropriate entry points for biotechnology products, exploit domestic and regional markets and build capacity to examine legal, social, environmental and ethical impacts of the advances in biotechnologies. African experts also

recommended the use of the New Partnership for Africa's Development (NEPAD) as an entry point into the continent's political agenda, while others stated the importance of a national strategy and public policy on genomics for funding and developing biotechnology.

Challenges in development and adoption of bitechnologies

National agricultural research capacities, environmental and food safety regulations, intellectual property rights (IPR) and agricultural input markets are important determinants of the size and distribution of economic benefits of breakthroughs in biotechnology. Many poor countries are still trying to establish biosafety policies for the first-generation transgenic plants (genetically modified organisms), while key infrastructure for their implementation is often inadequate. PDP technology, for example, faces the challenge of inadeqately equipped laboratories. The commercialization of PDPs is also impeded by concerns regarding biosafety and bioethics and by a lack of public awareness. There is also the potential for contamination and environmental risks because, for example, plants suitable for novel protein enhancement are often staple food crops in many developing countries. The absence of regulations designed specifically for the PDP sector creates concern related to contamination of food and environmental risks (Ma and others, 2005; Sabalza, Christou and Capell, 2014).

Medicines developed by multinational companies are often too expensive and many populations in developing countries cannot afford them

Medicines developed by multinational companies are often too expensive and many populations in developing countries cannot afford them. For example, a non-generic AIDS drug cocktail can cost up to $10,000 annually, while a generic version of AIDS drug developed by India costs only $300 — which may still be too costly for people in extreme poverty. Further, big pharmaceutical firms have little incentive to invest in products for treating or preventing diseases affecting poor countries because they produce low returns on investments in high-risk and costly biomedical R&D.

Developing countries have an opportunity to bridge the great health divide by making necessary investments in the development and use of indigenous biotechnogies

Along similar lines, vaccines for pandemic diseases such as measles have long been in use in developed countries but many developing countries have gained only limited access to those vaccines because they have become too expensive. In sum, vaccines and microbicides are not profitable products and the low return acts as a disincentive to private investment in biotechnologies in many developing countries (Salicrup and Fedorková, 2006). Developing countries have an opportunity to bridge the great divide in health outcomes by making necessary investments in the development and use of indigenous biotechnologies. However, support for the development of biotechnology therapies and products for endemic diseases requires infrastructure, well-educated and trained professionals, scientific excellence, regulatory infrastructure and sound health-care systems, all of which are often missing in many developing countries. The national health policies of less technologically advanced developing countries need to prioritize the potential of home-grown biotechnologies with sufficient financial, institutional and regulatory support.

Nearly 90 per cent of R&D in biotechnology is conducted in industrialized countries, where most genetically modified crops such as corn, rice and soybean, are planted. There is nevertheless little biotechnology research on crops such as cassava, white maize and millet, which are planted by poor farmers in sub-Saharan countries. Over the last 30 years, only 15 new drugs have been developed for tropical diseases, compared with 179 for cardiovascular diseases alone. It is also the case that the traits introduced in genetically modified crops tend to be geared towards existing farming practices of industrial agriculture rather than the local practices of small-scale farmers in developing countries (Azadi and Ho, 2010).

The strengthening of intellectual property rights in developed countries and large private investment in biotechnology have resulted in the concentration of key biotechnologies within a few firms

Moreover, the strengthening of IPR in developed countries and large private investment in biotechnology have resulted in the concentration of key biotechnologies within a few firms. Similar to biotechnology firms, companies in the food industry are unwilling to invest in research that is important for agriculture in poor countries owing to the limited market potential, fear of IPR-related piracy and the high cost to meet regulatory requirements. The genetic engineering of foods has also generated environmental and safety issues such as the rise of secondary pests, apart from the primary cotton pest, which can usher in unforeseen ecological changes. Indeed, application of insecticides has been as necessary for transgenic cotton (because of the presence of those secondary pests) as for non-transgenic cotton. Many developing countries are also yet to establish appropriate standards and monitoring rules. Further, there are gaps in communication among government regulators, farmers, scientists and multinational companies in respect of identifying the impact of genetically modified crops on biodiversity and food security, the risk of insects' resistance to genetically modified plant toxins and the ecological impact of the dissemination of genetically modified crops (ibid.).

Genetic modification technology and products also tend to be expensive and inaccessible to subsistence farmers in developing countries. Many less technologically advanced developing countries do not have the capacity to undertake the assessments and monitoring necessary to ascertain whether they would benefit from genetically modified crops and would be able to comply with safety regulations. In addition, genetic modification technology typically also requires adequate education and training of farmers, who may be willing to adopt the technique only if they can achieve an understanding of its use and can be convinced of its benefits (ibid.). Indeed, access to biotechnology by poor countries may also be prevented by the lack of research capacity to determine which biotechnologies would be most useful and how to deploy them, should they be adopted and potentially developed.

The domestic supply of skilled personnel generally depends on the level and composition of public and private investments in education. The universities that are able to develop biotechnologies often license them exclusively to private firms, which typically hold the rights to the sub-licensing of those technologies. Sometimes, these firms may not wish to sub-license a biotechnology in countries with a weak IPR regime, or even if they do market it, that biotechnology may be too expensive for the public sector.

The spreading of biotechnology can also be hindered by an ill-conceived regulatory system

The spreading of biotechnology can also be hindered by an ill-conceived regulatory system. If the regulatory process for genetically modified crops is expensive and time consuming, only large multinationals will be able to afford their commercialization. An expensive and unpredictable biosafety regulatory regime can also become a serious constraint on the commercialization of biotechnology developed by public research institutes because they are often less able, compared with entities in the private sector, to finance the ecological, health and agricultural trials needed to meet regulatory requirements (Ruane and Sonnino, 2011).

Strategies for taking advantage of the breakthroughs in biotechnologies

Taking advantage of breakthroughs in biotechnologies would require strengthening of biotechnological improvements in several areas, including infrastructures, innovation capabilities, human capital, development of enabling indigenous institutions and R&D expenditure. Availability of credit and the reduction of its cost are important determinants of whether poor farmers would adopt appropriate biotechnologies.

While it is necessary to increase the number of skilled scientists and public sector research, the generation of biotechnology products will also require creative arrangements for investment in research, including transfer of knowledge and lowering of barriers to the accessing of knowledge related to new products; as well as the development of a regulatory framework for maintaining a high level of safety.

International partnerships, both public and private, can play a significant role in strengthening the capacity for biotechnology innovation in developing countries

International partnerships, both public and private, can play a significant role in strengthening the capacity for biotechnology innovation in developing countries. Development partners will need to augment financial support and exchange of knowledge to foster human capital development and scientific capacity so as to pave the way towards sustained productivity growth and higher living standards. To improve the adoption and development of biotechnology in those countries, international organizations may need to encourage innovation and form collaborative alliances with institutions in many developing countries. Such technology transfer may be important for turning early-stage technologies into useable and commercially viable products. Moreover, adoption of open-source research practices in biotechnology can facilitate the development of treatments for specific diseases. Various patent pooling arrangements for a given technology can overcome the challenge posed by intellectual property fragmentation which prevents access to essential medicines.

Digital technologies: an opportunity for catching up or falling behind?

The present section explores the opportunities and challenges introduced by AI, automation and crowd-based technologies in developing countries. Notwithstanding the rapidity of the rise of these new technologies, their penetration in the economies of many developing countries has also proved equally rapid, providing opportunities for their populations, including consumers, while also posing challenges. The present subsection analyses early trends, possible positive and negative impacts and policy implications.

Automation and artificial intelligence

Automation and AI hold out the promise of new prosperity while also introducing risks of growing unemployment, underemployment and inequality

Advances in automation and AI, as discussed in previous chapters, are complementary and mutually reinforcing. Both sets of frontier technologies hold out the promise of new prosperity while also introducing risks of growing unemployment, underemployment and inequality. Currently, AI applications are developed and adopted mainly in countries at the technological frontier and in a few advanced developing countries. At the same time, the impacts of their potential applications in less technologically advanced developing countries can be wide-ranging and significant.

The actual and potential applications of AI in sectors such as manufacturing, transportation, language learning, health care and public administration can generate the kind of employment which would call for an increasingly more skilled workforce. Yet, with the right kind of investments in skills development, a less developed country can also acquire an edge in AI and machine learning. In fact, devising computer codes and algorithms — paving the way towards machine learning and, ultimately, development of AI capabilities — is relatively less capital-intensive than development of a competititve manufacturing base.

This presents less technologically advanced developing countries with a huge opportunity to invest in their populations—by enhancing educational systems, particularly

in the fields of science and technology, and creating training and skills development programmes — and to thereby catch up with countries at the technological frontier.

Less advanced developing countries can also take advantage of productive sectors that are making use of AI and investing their proceeds in less productive sectors

Less advanced developing countries can also take advantage of productive sectors that are making use of AI and investing their proceeds in less productive sectors so as to further improve productive capacities and expand effective demand through multiplier effects. In fact, data coming from sensors, wearables and individuals are already feeding new activities and creating jobs in data collection, tabulation and analysis, which are useful for generating higher value added and improved efficiency in agriculture, manufacturing and public administration (Ghosh, 2016; McKinsey Global Institute, 2017b).

In fact, the few software engineers and other skilled persons available in less advanced developing countries, either living overseas or at home, can serve as innovation leaders in enhancement, automation and absorption of AI in those countries, which can then take advantage of rapid technological change to invest in upgrading their education and health sectors through the use of suitable AI applications (Gurib-Fakim and Eloff, 2013).

A laissez-faire, laissez-passer approach to AI adoption in less advanced developing countries can weaken social cohesion and aggravate political discontent

Nonetheless, automation can also have negative social and economic implications. A laissez- faire, laissez-passer approach to AI adoption in less advanced developing countries — many with less diversified economies, deep technological divides and double-digit unemployment and underemployment rates — can weaken social cohesion and aggravate political discontent, possibly leading to increased domestic and international migration. The rate of vulnerable employment as a share of total employment in sub-Saharan Africa and South Asia has remained above 70 per cent and 65 per cent, respectively, in spite of their decline for the past 10 years (ILO, 2017)[4]. More broadly, the ILOSTAT database reveals long-term high levels of informal employment as a share of total employment for many developing countries.[5]

Automation (through robotization) and fragmentation of production systems (by new ICT and global value chains) can adversely affect countries that employ a significant number of economically active people in the agricultural sector. For example, the share of jobs at risk of being lost to automation and advanced technologies are above 50 per cent for Angola, Bangladesh, Cambodia, Ethiopia, India, Nigeria, the Philippines and Viet Nam (McKinsey Global Institute, 2017b). In addition, a few recent studies have reported that the impact of new technologies on labour markets has led to polarization of jobs — as discussed in chapter II — for countries at different levels of economic development, a trend expected to continue in the near term. For low-income countries, the changes in employment shares have on average been negative for the medium-skilled during 2000–2013 and slightly positive for the low- and high-skilled, while little change is expected during 2013–2021 in all skill categories. Likewise, for lower and upper middle income countries, both actual and expected changes in employment shares are, on average, quite positive for the high-skilled but negative for the medium- and low-skilled (ILO, 2018).

4 Vulnerable employment is defined as the sum of the employment status groups of own-account workers and contributing family workers.

5 The rates of informal employment for the following selected countries are for the period from around 2013 to 2016: Albania (63.5 per cent), Armenia (51 per cent), Bolivia (Plurinational State of) (70 per cent), Colombia (59 per cent), Dominican Republic (47 per cent), Egypt (54 per cent), El Salvador (68 per cent), Guatemala (79 per cent), Honduras (81 per cent), India (82 per cent), Liberia (80 per cent), Madagascar (91 per cent), Mongolia (47 per cent), Pakistan (83 per cent), Paraguay (57 per cent), Peru (60 per cent) and South Africa (46 per cent).

Dormehl (2017) indicates that some chief executive officers (CEOs) of big companies in developing countries are increasingly encouraged to "hire" AI machines, which can be less costly and more productive than workers, who may periodically leave on vacation, get sick or demand higher wages. In urban areas of poor countries, increasing automation through the introduction of driverless cars and less labour-intensive manufacturing and services can also be disruptive owing to fewer income-earning opportunities for blue-collar workers and weaknesses in or lack of social protection systems (Citi GPS and Oxford Martin School, 2017).

The main question is whether less advanced developing countries would be able to create more jobs without massive training and retraining programmes on digital technologies

The main question is whether less advanced developing countries would be able to create more jobs without massive training and retraining programmes on digital technologies. According to Brynjolfsson (2011), "AI and automation would continue making the economic pie bigger, but there is no economic law that guarantees that everyone, or most people, will benefit". At the same time, the growing ubiquity of AI applications presents less developed countries with the opportunity to invest in their populations by launching online science and technology education courses; enhancing apprenticeship and retraining programmes; and upgrading R&D and innovation systems (Haider, 2018; Tegmark, 2017; Gurib-Fakim and Eloff, 2013).

The implementation of protectionist policies for inward-looking growth by frontier countries and reshoring of manufacturing activities can also harm current prospects for growth and development in less technologically advanced developing countries. The "labour-cost advantage" can quickly disappear, further eroding the fragile employment situation in those countries in the foreseeable future. Yet, the potential use of 3D printing, partly enabled by AI technologies, may create both opportunities and challenges in developing countries with labour-cost advantage exports (see box III.1).

Global value chains have exploited the labour-cost advantage—i.e., the sweatshop-type[6] labour conditions and environmental degradation characteristic of countries where labour laws and regulations can more easily be circumvented (Shum and others, 2016). The medium-term objective of achieving the 2030 Agenda for Sustainable Development makes it more imperative to put social development in the driving seat, so that this labour-cost advantage, based on low wages, can no longer be an adjunct of future sustainable development.

Less advanced developing countries would take longer than countries at the technological frontier to adjust human capacities and infrastructures so as to truly benefit from AI

Overall, less advanced developing countries would likely take longer than countries at the technological frontier to adjust human capacities and infrastructures so as to truly benefit from AI. For this reason, policymakers in poor countries need to prepare their populations and economies for new industries which would create new occupations and for jobs that value human creativity and social interaction. On the other hand, swift adoption of AI without any concomitant plan on how to redistribute the income generated from highly productive sectors to less productive ones may prove more detrimental than beneficial, at least in the short-term. Full and decent employment should be a medium-term objective based on implementation of new models of education, lifelong learning and regular (re)training programmes.

6 Sweatshops are characterized typically by low wages, long working hours and unhealthy working conditions, particularly for women, children and migrant workers.

Box III.1

Opportunities and challenges presented by 3D printing

While a number of developed countries use 3D printing in the construction, manufacturing, aeronautics and health sectors, 3D printing would also open opportunities to less advanced developing countries and countries in special situations, in particular. 3D printing can offer opportunities by overcoming infrastructure bottlenecks and lowering the barriers to manufacturing leapfrogging and exports. It can create opportunities for countries without the technical capacities to develop an entire industrial supply chain.

3D printing can therefore economically empower small businesses by providing more people with access to the means of production. It can also reduce the role of needed economies of scale and contribute to reducing the gap between small and large firms. For example, 3D printing technology can enable the manufacture of local equipment such as toys, farming and domestic tools and spare parts, which could directly improve the livelihood and productivity of small firms, creating new jobs and empowerment in terms of their economic outlook.

Challenges

In the immediate short term, 3D printing can depress import demands from developing countries and create more localized 3D printing production hubs near large consumer and highly developed markets (Hallward-Driemeier and Nayyar, 2018, p. 100). As 3D printing further matures, less advanced developing countries, particularly those relying on low-cost mass manufacturing production, could lose a large amount of business to do-it-yourself manufacturers (Bryane, 2013).

To take advantage of the opportunities provided by 3D printing, developing countries would need to overcome existing technological gaps by investing in access to and adoption of affordable, clean and reliable electricity, improving access to high quality health care and education, and investing in science and engineering-related R&D. The success or failure of 3D printing would depend on improvements in infrastructure, in particular in areas related to energy and the Internet.

In the event that the above challenges can be overcome and the cost of adopting 3D printing declines sufficiently, enhanced international cooperation could further facilitate access to and adoption of 3D printing as a means of supporting economic transformation and industrial development.

Source: UN/DESA.

Crowd-based technologies

Crowd-based technologies form the basis of the so-called sharing economy, which resembles a mix of "gift" and "market" economies in its transactions. Sundararajan (2016) argues that these technologies, characterized by an array of on-demand platforms, are transforming a large number of industries, including transportation, hotels, banks and marketplaces.

Crowd-based technologies have already created new occupations and sources of income generation for individuals and families in less developed countries

Crowd-based technologies have already created new occupations and sources of income generation for individuals and families in less developed countries. Airbnb, for example, has made it possible for an empty room in the home of an individual or household to become a source of income — a support in terms of meeting expenses or even saving for the future. At the same time, the price, relative to that for booking a room in a hotel, is generally attractive to the service user. Similarly, Uber, BlaBlacar and other crowd-based businesses are able to entice clients with their offer of relatively trustworthy and more affordable taxi and transportation services relative to regular taxi, bus or train services. As Sundararajan puts it, "digital trust powers the sharing economy".

Taxi drivers, however, are not necessarily shifting to the new platforms completely. Instead, they often juggle both regular taxi and Uber services, making the best use of both, which will depend on time of day and passenger pickup location. In these types of businesses, both the consumer and the service provider can benefit, without a high degree of risk, aside from the investment costs incurred by the service providers in, say, modernizing their home or a room in that home or purchasing a car. Overall, crowd-based businesses are growing and penetrating all kinds of economic activities, functions and sectors, such as banking (e.g., Lending Club), hotels (e.g., Airbnb), retail (e.g., Etsy), transportation (e.g., Uber, Ola (India)), diversified labour (e.g., Handy), personal services (e.g., Munchery), corporate services (e.g., HourlyNerd), car rental (e.g., Getaround) and risk capital intermediaries (e.g., Kickstarter).

Again, according to Sundararajan, a sharing economy underpinned by crowd-based platforms reflects a new way of organizing economic activity, workers and consumers. Through its peer-to-peer commercial exchanges, the sharing economy blurs the line between the personal and the professional. It is therefore more difficult to determine its impact on the economy, government regulation, labour markets and the social fabric.

One of the important challenges presented by crowd-based platforms is how to help workers, drivers and renters avoid low wages or income

One of the important challenges presented by crowd-based platforms is how to help workers, drivers and renters avoid low wages or income. Other challenges are associated with their lack of social protection and inadequate safety conditions. Many developing countries typically have very low levels of social protection or none at all, while their weak labour-market institutions are less able to negotiate adequate working conditions for workers (ILO, 2014). Nonetheless in some countries, there has been support for the functioning of local crowd-based platforms to enable them to compete with transnational platforms. In India, for example, Ola, by virtue of the fact that it has the capacity to service remote areas, is thereby able to compete with Uber for the same clientele, even if Uber offers better prices.

As noted above, the crowd-based share-economy models raise serious issues regarding social protection. For one thing, they blur the line between employer and employee. Serious equity and ethical questions revolve around the subject of responsibilities: how do the platforms, participants and workers in the shared economy and Governments go about contributing their fair share of social protection? It is argued that most of the income generated is funnelled to a few monopoly firms with headquarters in the big cities of developed countries, which compounds the challenges faced by poor countries with respect to how to adequately regulate the sharing economy (Ross, 2017). Crowd-based platforms — matching buyers and sellers of a particular product or service — typically collect a hefty share of the gross revenue, while participants and workers on the platform provide capital and labour services as well (as attested, e.g., by the cost of roads, vehicles or home improvement), but receive a relatively less equitable share of the revenue.

Rapid deployment and growth of crowd-based technologies are raising additional concerns regarding consumer protection and safety

The rapid deployment and growth of these technologies are raising additional concerns related to consumer protection and safety. For example, it is often the case that women feel less safe when renting a room in a home, where privacy and security are not guaranteed, or when employing a car service to travel long distances or to remote areas. And many less advanced developing countries have yet to implement effective safety and security norms designed to protect people from the risks associated with participation in crowd-based platforms.

Another relevant issue being discussed increasingly is how Governments in less advanced developing countries could go about levying taxes on the use of roads, land, electricity and other public services, which serve as a foundation for the development of

crowd-based platforms that benefit both transnational firms and consumers. What would be the criteria for measuring the contribution of employers and workers to income generation and using the figures obtained as a basis for fixing tax rates?

Conclusion

The impacts of crowd-based technologies and AI on developing countries are yet to fully materialize and those impacts will vary across countries and depend on the level of development, quality of institutions and policy flexibilities for coping with the effects of these technologies. The Governments of developing countries will need to upgrade their capacities for regulating crowd-based platforms and collecting taxes on the revenues that they earn in these countries, as discussed in chapter V. However, possible strategic options may not apply specifically to all of these countries. These options include, but are not limited to, the provision of a basic income to people unemployed and underemployed, the broadening of social protection floors, and innovative taxation systems designed to distribute more fairly the income generated by firms and high-income earners and thereby help to support innovation as well as the financing of social security.

As discussed, AI and automation can generate significant unemployment and underemployment of the low- and medium-skilled, at least in the short term, in less technologically advanced countries, particularly those with high shares of informal employment. Therefore, expected employment outcomes and policy design should be carefully assessed before further transfer and development of frontier technologies is undertaken.

On the other hand, new technologies have the potential to create new occupations, representing opportunities for decent employment, if appropriate policies are crafted. In this context, Governments in these countries will need to increase their investments in building and upgrading the skills of the workforce and quality digital infrastructure, including in broadband Internet access, in order to suppport a sustainable development framework. First-order investments can be directed towards training and retraining programmes, apprenticeship programmes, and education focused on life-long learning, project-based creativity and peer-based approaches.