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TECHNOLOGY AND INNOVATION REPORT 2021

Catching technological waves

Innovation with equity

OVERVIEW

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OVERVIEW

CATCHING TECHNOLOGICAL WAVES
Innovation with equity

Human development in recent decades has been accompanied by rapid changes in technology and an increasing proliferation of digitized devices and services. And the pace of change seems likely to accelerate as a result of "frontier technologies" such as artificial intelligence (AI), robotics, biotechnology, and nanotechnology.

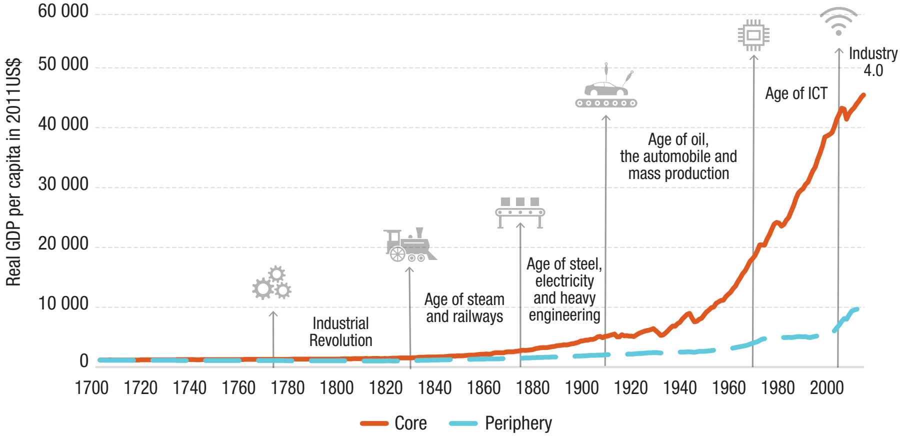
These technologies have already brought enormous benefits – dramatically highlighted in 2020 by the accelerated development of coronavirus vaccines. But rapid advances can have serious downsides if they outpace the ability of societies to adapt. There are fears, for example, that jobs are disappearing as more economic activity is automated, and that social media is exacerbating divisions, anxiety and doubt. Overall, there are concerns that frontier technologies will further widen inequalities, or create new ones.

Most of these issues have been voiced in developed countries. But the implications could be even more serious for developing countries – if poor communities and countries are either overwhelmed or simply left behind. This report considers how developing countries can catch the wave of frontier technologies, balancing innovation with equity in pursuit of the Sustainable Development Goals.

1. Catching the waves

We live in an age of dramatic technological advances, mostly concentrated in developed countries, but the great divides between countries that we see today started with the onset of the first industrial revolution. At that point most people were equally poor and the gaps in per capita income between countries were much smaller (Figure 1). Then with waves of technological change, Western Europe and its offshoots – Australia, Canada, New Zealand, and the United States – along with Japan, pulled ahead. Most other countries remained on the periphery. Every wave of progress was associated with sharper inequality between countries – with widening disparities in access to products, social services and public goods – from education to health, from ICT infrastructure to electrification. Nevertheless, a few countries, notably in East Asia, were subsequently able to catch up through technological learning, imitation and innovation.

Figure 1
Technological change and inequality through the ages



Source: UNCTAD, based on data from Maddison Project Database, version 2018, Bolt et al. (2018), Perez (2002), and Schwab (2013).

Notes: "Core" corresponds to Western Europe and its offshoots (Australia, Canada, New Zealand and the United States) with Japan. "Periphery" corresponds to the world, excluding the "core" countries.

Prosperity with inequality

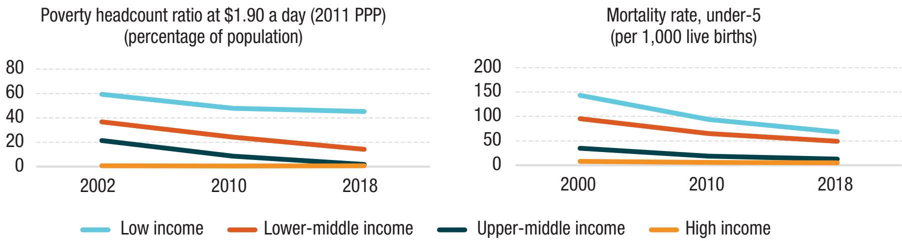
During recent decades of digitization, the world has seen growing prosperity. People on average are living longer and healthier lives. Rapid economic growth in emerging economies has fuelled the rise of a global middle class. Nevertheless, there is persistent poverty, and rising inequality. Wealth is highly concentrated, and there are also large disparities in income-earning opportunities, as well as in standards of education and health. These imbalances constrain economic growth and human development while heightening vulnerability, whether to pandemics, or economic crises or climate change – and can soon destabilize societies.

Multifaceted inequalities

Inequality is a multifaceted concept related to differences in outcomes and opportunities between individuals, groups or countries. These differences can arise along any dimension of development – social, economic or environmental. Inequality of outcomes and opportunities are closely intertwined. The outcomes for one generation affect the opportunities for the next – resulting in intergenerational transmission of inequalities.

As indicated in Figure 2, there are still large inequalities between countries. People in low- and lower-middle-income countries, on average, suffer from much higher levels of poverty and deprivation when compared with people in upper-middle- and high-income countries.

Figure 2
Gaps between country groups, selected SDG indicators



Source: UNCTAD based on data from the World Bank.

Wide income gaps

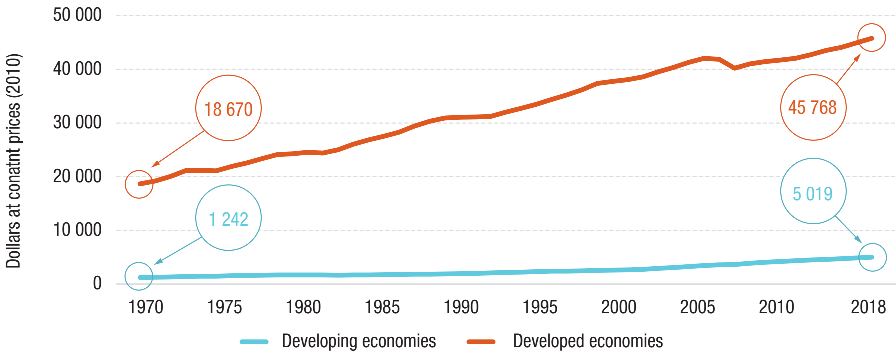
Many of the inequalities correlate with levels of income. In the past 10 to 15 years, global income inequality has decreased, mainly because large developing countries, mostly in Asia and notably China, have grown faster and started to catch up. However, achievements in global equality are threatened by rising disparities within countries. Over the past 40 years, within-country inequality has increased not only in some developed countries such as the United States, and in Europe, but also in developing countries such as China and India.

Given that within-country inequality is rising, while the disparities between countries are falling, what is the net effect? To answer that question, we must consider the contribution of both types of inequality to global inequality. Estimates suggest that between-country inequality now dominates. Between 1820, the onset of the industrial revolution, and 2002, the contribution of between-country inequality to global inequality rose from 28 to 85 per cent. In other words, in 1820, global income inequality was driven by class divides within countries. Now it is driven more by the lottery of birthplace: a person born in a poor country suffers a 'citizen penalty'.[1]

Since it is the dominant component, the recent relative reduction in inequalities between countries may be a cause for celebration. But it should disguise the fact that in absolute terms the gap between developed and developing countries has never been higher and continues to increase (Figure 3).

Figure 3

Average GDP per capita in developing and developed economies, 1970-2018



Source: UNCTAD calculations based on UNCTADstat.

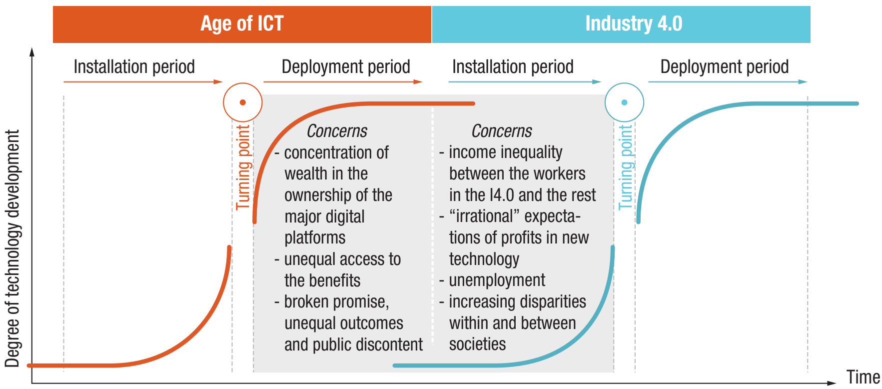
Two-phase revolutions

There is no consensus on the dynamics of economic inequality – which is affected by many factors, such as war and epidemics, as well as by political processes influenced by power struggles and ideologies. Globalization and technological change have also been pointed out as drivers of income inequalities within countries. Nevertheless, at the same time these impulses have helped reduce poverty in low-income countries, and not only in larger, faster developing ones, such as China and India, but also many others, including countries in Africa, as shown by the impact of smartphones.[2]

At the same time, inequality is also affected by technological revolutions. Technological changes combine with financial capital to create new techno-economic paradigms – the cluster of technologies, products, industries, infrastructure and institutions that characterize a technological revolution. In the countries at the centre of these new technological waves, the surge can be considered in two phases. First is the installation phase as technology is introduced into core industries – widening the gaps between workers in these industries and the rest. Second is the deployment phase which also tends to be uneven: not everyone gets immediate access to the benefits of progress such as a life-saving treatment, or access to clean water. The result is widening divisions which can lead to public discontent.

At present, the world is reaching the end of the deployment phase of the "Age of ICT" and starting the installation phase of a new paradigm, involving frontier technologies and sometimes called Industry 4.0 (Figure 4). The deployment of ICT resulted in an enormous concentration of wealth in the ownership of the major digital platforms. How will Industry 4.0 affect inequalities between countries? Much will depend on whether countries are catching up, forging ahead, or falling behind – which in turn will depend on their national policies and on their involvement in international trade.

Figure 4
Technological revolutions and inequalities



Source: UNCTAD based on Perez (2002).

Responding to inequalities

To some extent governments can mitigate inequalities within countries through progressive taxation on incomes or wealth, or on income from capital. They can also make services such as education freely available to all. Governments can also increase social transfers, such as unemployment benefits, which reduce the risk of people falling into poverty. And in the workplace these actions can be complemented by those of stronger trade unions which help to increase wages.

Reducing income inequality between countries will mean harnessing technology and trade for structural transformation. If developing countries are to create economies that offer their people better-paid jobs they will have to take advantage of the new technological paradigm. Developing countries, and whole continents such as Africa, cannot afford to miss this new wave of technological change.

2. Forging ahead at the digital frontiers

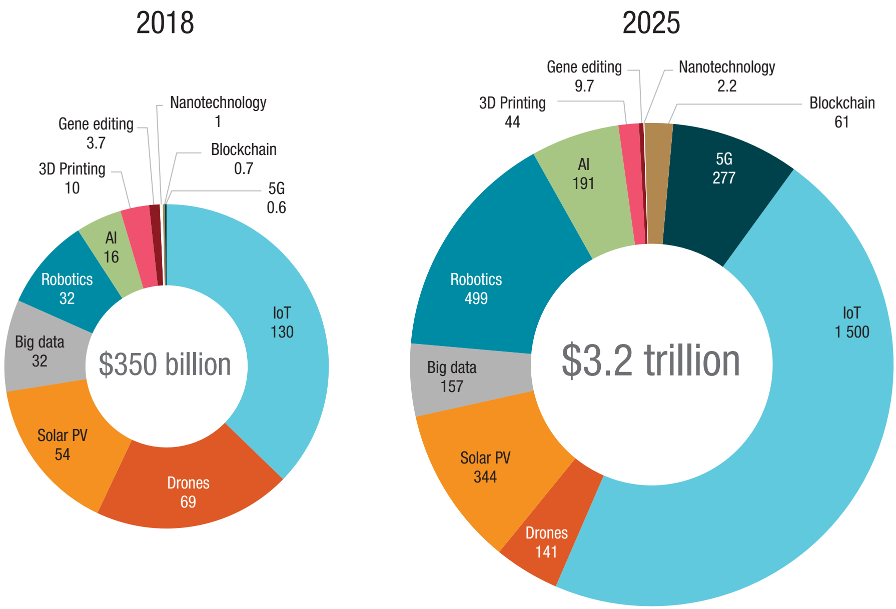
The "frontier technologies" are a group of new technologies that take advantage of digitalization and connectivity which enable them to combine to multiply their impacts. This report covers 11 such technologies: artificial intelligence (AI), the Internet of things (IoT), big data, blockchain, 5G, 3D printing, robotics, drones, gene editing, nanotechnology and solar photovoltaic (Solar PV).

These technologies can be used to boost productivity and improve livelihoods. AI, for example, combined with robotics can transform production and business processes. 3D printing allows faster and cheaper low-volume production and rapid, iterative prototyping of new products. As a group, these 11 technologies already represent a $350-billion market, and one that by 2025 could grow to over $3.2 trillion (figure 5).

Finance companies have used these technologies, for example, for making credit decisions, and for risk management, fraud prevention, trading, personalized banking and process automation. The manufacturing sector has used them for predictive maintenance, quality control and human-robot combined work.

Many of the major providers of these technologies are from the United States which is home to major cloud computing platforms. China is also a major producer, notably of 5G, drones and solar PV. For each of the technologies, these two countries are also responsible for 30 to 70 per cent of patents and publications.

Figure 5
Market size estimates of frontier technologies, $billions



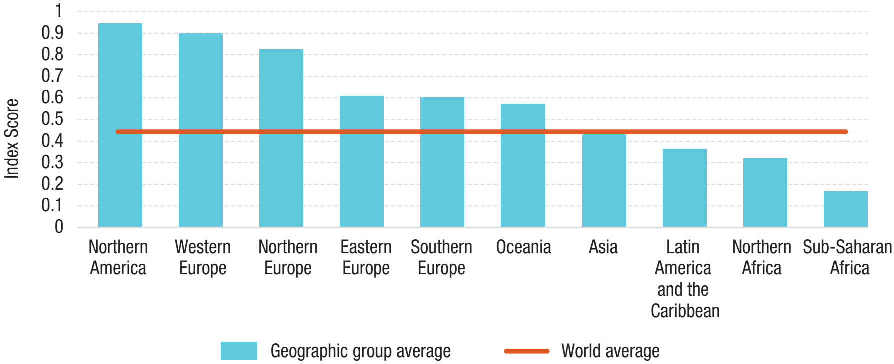
Source: UNCTAD based on data estimates from Froese (2018), MarketsandMarkets (2018), Sawant and Kakade (2018), Business Wire (2019), Chaudhary et al. (2019), GlobeNewswire (2019), MarketsandMarkets (2019), MarketWatch (2019a), MarketWatch (2019b), Raza (2019), Tewari and Baul (2019), Wagner (2019), Mordor Intelligence (2020).

A country readiness index

Only a few countries currently create frontier technologies, but all countries need to prepare for them. To assess national capabilities to equitably use, adopt and adapt these technologies this report has developed a 'readiness index'. The index comprises five building blocks: ICT deployment, skills, R&D activity, industry activity and access to finance.

Based on this index, the countries best prepared are the United States, followed by Switzerland, the United Kingdom, Sweden, Singapore, the Netherlands and the Republic of Korea. The list also has high rankings for some transition and developing economies – such as China ranked at 25 and the Russian Federation at 27. Most of the least-ready countries are in sub-Saharan Africa, and in the developing countries generally.

Figure 6
Average index score by geographical group



Source: UNCTAD.

The countries ranked highest are largely the richest ones, but there are many outliers – countries that perform better than their per capita GDPs would suggest. The greatest overperformer is India, followed by the Philippines. On the R&D components of the index, China and India perform well, partly because these countries have abundant supplies of highly skilled but relatively inexpensive human resources. In addition, they have large local markets, which attract investment from multinational enterprises. Viet Nam and Jordan also do well, reflecting supportive government policy.

3. Humans and machines at work

Technological change affects inequalities through its impact on jobs, wages and profits. These inequalities could arise between occupations, firms and sectors as well as between wage earners and owners of capital. Another level in which inequality emerges is in the differences in the economic structures of countries. The contribution of each of these and other elements to income inequality depends on many factors, such as the country's level of development, its economic structure and its social and economic and labour policies, as well as the size of a specific sector or its firms. Therefore, at any given time, in a particular country, technological change could cause inequality to rise or fall.

Is this any different from what happened with previous waves of technology? In principle, no. The channels and mechanisms are similar. But each wave of technological change brings inequality in new shapes.

Automation taking jobs

Nowadays, a major concern is that AI and robotics will reduce employment. Indeed, since the onset of the industrial revolution workers have expected new technologies to destroy jobs. Generally this has not happened; new technologies have instead tended to create more jobs, and of different kinds. But for frontier technologies, the situation could be different because the changes are coming so quickly they could outpace the capacity of societies to respond.

Previously, many jobs were considered safe because it was difficult to teach computers how to perform them. Now, however, the computers can often teach themselves. Some estimates suggest that over the next 20 years, in Europe and the United States 30 to 50 per cent of jobs could be automated. Others see a more modest impact – from 8 to 14 per cent across occupations. Nevertheless, while some jobs will disappear, others will emerge – such as those requiring empathy, ethical judgements, inventiveness, managing unpredictable changes, or making decisions based on understanding tacit messages – all of which have to be carried out by humans.

Predictions on job losses are typically based on technological feasibility, but the more important factors are often economic. Even when it is technologically feasible, capital may not replace labour; much depends on relative prices. At the same time, the overall demand for labour could be increased by macroeconomic effects.

Another concern for developing countries is that multinational enterprises could take advantage of frontier technologies to keep production at home – or to reshore manufacturing that had previously been moved overseas. This process could slow the shift of traditional industries such as garments, footwear, and low-tech electronics from China to less-industrialized countries in Asia and Africa. The feasibility of reshoring does, however, depend on many other factors, including ownership, and the scale of production, and the country's position in the supply chain. It may also make more sense to keep production in developing countries that have growing populations and expanding middle classes which offer prospects of growing markets.

Job polarization

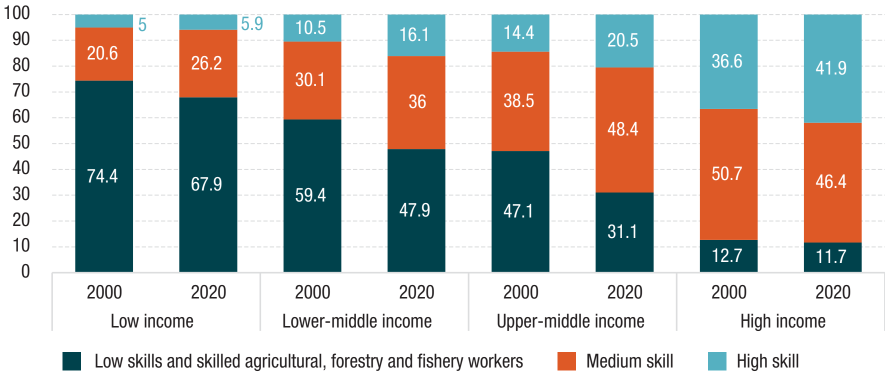
Job displacement can also be accompanied by job polarization, which refers to an expansion in high- and low-wage jobs combined with a contraction in middle-wage jobs. In developed countries there are, for example, now fewer clerks doing routine middle-wage jobs. Thus far, there has been less impact on the lowest-skill manual jobs, but that seems set to change with greater use of AI and nimbler robots.

Not all job polarization can be attributed to technological change, much will also have been an outcome of trade and international competition. In developed countries job polarization has been associated with a reduction in manufacturing and medium-skill jobs, and an increase in services and higher-skill jobs, while in middle-income countries there has been an increase in manufacturing and medium-skill jobs (Figure 7).

The wide differences in the economic structure of low, middle and high-income countries, as well as the unequal impact of international trade, are expected to also reflect in an uneven impact of frontier technologies on job polarization in different economies. In this regard, low- and middle-income countries are likely to be less affected.

Figure 7

Employment by skill level, country income grouping (percentage of total civil employment)



Source: UNCTAD based on data from ILOStat according to the ISCO-08.

The gig economy

Frontier technologies are being used to provide services via digital platforms that have spurred the creation of a 'gig economy'. Some of this work is locally based, but there is also "cloud work" that can be performed anywhere via the Internet. While the gig economy provides employment, this is typically on insecure terms, creating a precarious class of dependent contractors and on-demand workers. The consequences for inequality will depend on whether the gig workers are poor people who would otherwise be unemployed, or middle-class people looking for small additional incomes. Inequality will certainly rise if these jobs replace better-paid ones or replace full-time jobs with part-time ones, or if profits grow faster than salaries. The gig economy may also heighten gender inequality: women are less likely to be working on digital platforms, but they often do so for more hours than men and for significantly lower wages.[3]

If service occupations are tradable internationally, salaries may converge. This has happened in computer coding, for example, and in digital design as well as in medical diagnostics, paralegal assessments, and image recognition.

Market and profit concentration

These new digital platforms benefit from network effects, so that markets tend to concentrate, leaving a small number of large players. This reduces the incentive to cut prices – producing higher profits which can widen inequality between wage earners and the owners of capital. And for some IT skills these companies may be virtually the only employers – a "monopsony". With few companies there is also the temptation for tacit collusion as a result of data exchange through algorithms.

AI and global economic inequalities

The impact of AI on inequality between countries will depend to some extent on the type of input data. If AI primarily uses 'big data' generated by users, this would mainly benefit the United States and China, whose competing digital platforms gather massive amounts of such data. But if it primarily uses big data gathered by the Internet of things this would benefit other economies with strong manufacturing bases– such as the EU, Japan and the Republic of Korea.

A third AI scenario involves allowing computers to learn more like humans through repeated interactions of AI models. This would not particularly benefit the United States or China, but would still demand resources and capabilities more likely to be found in the developed countries, which would enable them to pull further ahead of the developing countries.

Widening technological gaps

There is also a fear that the widespread adoption of frontier technologies in developed countries will reduce the labour-cost competitiveness of today's less industrialized economies in Asia and Africa, increase the technological gaps between them and developed countries – make it more difficult to catch up, diversify their economies, and create jobs. In the past, countries like China, Mexico, Brazil, and a handful of Asian countries moved up the income ladder by transferring labour and capital from relatively lower-productivity agriculture to higher productivity manufacturing and services. The fear now is that frontier technologies and Industry 4.0 will upend these traditional development processes, making a difficult journey even harder.

Challenges for developing countries

Theories and models point to possible channels of impact, but the actual effect will depend on the sectors affected, on the capacities of countries, and on the policies and strategies adopted. However, experience shows that over time new technologies are likely permeate to various sectors of the economy and social activities. In these circumstances, developing countries should deliberately adapt and use automation to increase productivity, promote economic diversification and create jobs. Preparing people, firms and institutions for such changes can limit any negative effects on inequality.

In pursuing these policy objectives, developing countries will need to overcome a number of challenges.

- *Demographic changes* – Low-income- and lower-middle-income countries typically have expanding and younger populations – which will increase the supply of labour and depress wages, reducing the incentives for automation.
- *Lower technological and innovation capabilities* – Low-income countries have fewer skilled people and depend to a large extent on agriculture which tends to be slower to take advantage of new technologies.

- *Slow diversification* – Developing countries typically innovate by emulating industrialized countries, diversifying their economies, and absorbing and adapting new technologies for local use, but this process is slowest in the poorest countries.
- *Weak financing mechanisms* – Most developing countries have increased their R&D expenditures, but these are still relatively low. The African Union, for example, has established a target of one per cent of GDP, but on average sub-Saharan African countries are still at 0.38 per cent.[4] There is very little private funding of industrial technologies for productive applications.
- *Intellectual property rights and technology transfer* – Stringent intellectual property protection will restrict the use of frontier technologies that could be valuable in SDGs related areas such as agriculture, health and energy.

Accelerating towards industry 4.0

Many national and local governments are working to stimulate the growth of new industries and services that produce jobs and wealth and promote human development. To be fully effective, they need to set strategic directions through national plans for research and innovation which can take on emerging social challenges such as ageing and regional disparities.

National innovation policies also need to align with industrial policies. Keeping national or regional industry competitive is a central goal in most strategic plans for AI and Industry 4.0 technologies. These plans can take advantage of UNCTAD's *Framework for Science, Technology, and Innovation Policy (STIP) Reviews* which can lead to specific policies for harnessing frontier technologies for smarter, more sustainable cities, food security and smart agriculture, and employment generation in smarter factories.

In many cases this will require access to patented technologies. One option is compulsory licensing, but there can also be more collaborative agreements, along with patent pooling, clearing houses, and open-source licensing. At the same time, governments can finance R&D while requiring that the benefits of this research serve the public good.

Some of the finance for innovations can come from official sources, but alternative models for funding include impact investment, venture capital, crowdfunding, and Innovation and technology funds. There have been some successes: in 2018, annual equity funding for tech startups in Africa doubled to more than $1 billion.

At the same time, policymakers need to anticipate the impacts on the workforce. To take full advantage of these technologies, workers will need competencies in science, technology, engineering and mathematics (STEM) – as well as in design, management and entrepreneurship. Workers who cannot be trained or retrained, and lose their jobs, should be able to rely on stronger mechanisms of social protection and workfare as well as on different forms of income redistribution such as negative income tax, and universal basic income. There is also a renewed importance of labour unions to defend workers' rights and legitimate concerns about their jobs in the digital economy and the increasing automation of tasks.

Finance for such measures could come from "robot tax" which would gather income from the technologies that replace workers. Or there could be an automation tax, combined with removing corporate tax deductions for investment. On the other hand, rather than taxing individuals or technologies, it might be better to tax the resulting wealth.

4. Innovation with equity

Frontier technologies have huge potential for improving people's lives and protecting the planet. During the COVID-19 pandemic, for example, AI and big data have been used for screening patients, monitoring the outbreaks, tracking and tracing cases of the disease, predicting its evolution and assessing infection risks. Other examples have ranged from the use of IoT to monitor the quality of groundwater in Bangladesh, to the use of drones for delivering medical supplies to remote communities in Rwanda and Ghana.

But technology is rarely a solution on its own. Problems such as poverty, hunger, climate change or inequalities in health or education are inevitably complex and multidimensional. Technology, frontier or otherwise, may support initiatives of all kinds, social, political, or environmental, but all technology needs to be used carefully if it is to help rather than hinder, or produce unintended side effects.

Technologies are likely to have an effect on disparities, but inequalities can also shape technologies – so that they reflect, reproduce and perhaps amplify systemic bias and discrimination. Currently most technologies are created by firms in the global North and predominantly by men. They tend to focus on the demands of the rich, crowding out innovations that might benefit the poor. Technological change is also shaped by gender inequalities, partly because men have been more likely than women to study STEM subjects.

Technologies affecting inequalities through access and design

People are affected as consumers of goods and services that apply frontier technologies. One of the most critical aspects is access – which can be considered to comprise a combination of "five A's": availability, affordability, awareness, accessibility, and ability for effective use. Access to technology can also be restricted by social norms – for women, ethnic minorities and other disadvantaged groups, even within the same household.

Another important aspect is design. Developers should also be mindful that how they design, and people use, technologies can have unintended consequences.

Risks of bias and discrimination

Many concerns are related to the biased design and unintended consequences of AI. Biases within AI systems can arise in a number of ways, either because they employ biased algorithms, or they use biased data for training. For example, AI can perpetuate stereotypes and reduce the benefit of products for women.

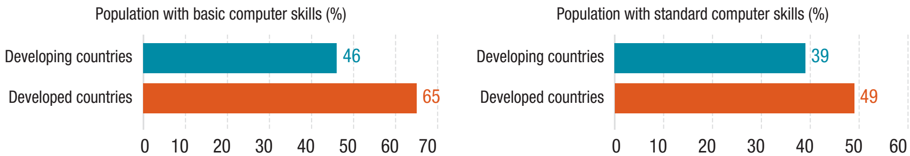
The benefits are also likely to be unevenly distributed in the case of gene editing: most of the research is in richer countries with the prospect of monopoly ownership of technologies, which could limit their contribution to achieving the SDGs, particularly those related to food production and health. Gene editing also raises ethical questions of what constitutes an ideal human being. This could result in an underclass of people who cannot afford genetic treatment.

Challenges for developing countries

Developing countries face three main challenges in promoting equal access to the benefits of frontier technologies:

- *Income poverty* – Many people in developing countries cannot afford new goods or services, particularly those in rural areas. In this case the barriers are not technological but economic and social.
- *Digital divide* – Many frontier technologies rely on steady, high-speed fixed Internet connections, but almost half of the world's population remains offline. Many developing countries lack adequate digital infrastructure, and for most of their people Internet costs are prohibitive.
- *Shortage of skills* – In developing countries, the basic and standard skills are on average 10 to 20 percentage points lower than in developed countries (Figure 8). Many frontier technologies require at least literacy and numeracy skills. Other technologies require digital skills, including the ability to understand digital media, to find information, and to use these tools to communicate with others.

Figure 8
Gaps in digital skills



Source: UNCTAD based on ITU (2018, 2019).

Directed to sustainable development

To overcome these challenges, Governments and the international community need to guide new and emerging technologies so that they support sustainable development and leave no one behind. From the outset, it will be important to establish ethical frameworks, particularly for the deployment of AI. Many voluntary initiatives are already aiming to ensure that the processes and outcomes are fair, transparent, accountable, and inclusive. Similarly, for human germline gene editing there needs to be a broad consensus on ethical and societal issues.

Governments should also try to foster supportive innovation ecosystems, based on assessments that analyse different techno-system paths and their impacts on inclusive and sustainable development. An example of international cooperation which assists with that task is UNCTAD's programme on STI Policy Reviews.

The chosen technologies then need to be deployed at scale, with plans to pass the baton from scientists and engineers to entrepreneurs and others, and to boost household incomes. The technologies can also be embedded in services provided by the public sector, with special attention for underserved areas that are not commercially viable for private companies. Networks of activists, academics, and practitioners can experiment with alternative possibilities – based on local knowledge and driven by environmental and social needs.

5. Preparing for the future

Technological progress is essential for sustainable development, but can also perpetuate inequalities or create new ones, either by limiting access to more privileged groups and affluent countries, or through built-in biases or unintended consequences. The task for governments is thus to maximise the potential benefits, while mitigating harmful outcomes, and ensuring universal access. Countries at all stages of development should promote the use, adoption and adaptation of frontier technologies, preparing people and firms for what lies ahead. An important requirement is effective national governance: the state needs to create the vision, the mission and the plan for creating and shaping the market for inclusive and sustainable innovations.

Governments will also need to invest in human and physical resources. To help them do so, developing countries should be able to rely on international cooperation, communities of nations working together to build an international institutional framework that embraces countries at all stages of technological development.

These official policies and programmes will need to be supported by vigorous social activism, with people and organizations cooperating to identify mismatches between technological innovation and societal responses. Keeping the SDGs as central guiding principles will require constant vigilance from civil society organizations.

For reducing inequalities, governments can draw from a broad range of instruments including regulatory measures and economic and fiscal instruments, as well as smarter policies on trade, investment, industry, education and innovation. They can also ensure that vulnerable and low-income groups have access to valuable new goods and services some of which can be subsidized or provided free.

Twin technology targets

To catch up and forge ahead, developing countries will need to adopt frontier technologies while continuing to diversify their production bases by mastering existing technologies. They need to keep to both targets in sight. This will mean strengthening innovation systems, while aligning STI and industrial policies, building basic digital skills, and closing gaps in ICT infrastructure.

- *Strengthen national innovation systems* – Governments should engage a wide range of actors who can help build synergies between STI and other economic policies – industrial, trade, fiscal, and monetary, as well as educational policies.
- *Align STI and industrial policy* – Together these should attract firms into the core sectors of frontier technology development and deployment. This would enable traditional production sectors to benefit from multiple channels of diffusion, covering foreign direct investment, trade, and intellectual property rights, patents and the exchange of knowledge and know-how.
- *Develop digital skills* – Education and training programmes should be inclusive and specifically involve women.
- *Focus on the furthest behind* – Countrywide access to electricity and to ICT should aim to bridge gender and generational gaps. Through inclusive National Digital Agendas countries can focus on the furthest behind, leveraging ICT infrastructure and improved Internet access through fixed or mobile broadband.

Mitigating risks

There is always the risk that rapid technological change will cause harm or perpetuate or accentuate inequalities. This should prompt public responses to:

- *Strengthen social protection* – During labour market disruptions workers should be able to rely on robust systems of social protection. Options include universal basic income schemes which might be financed by taxing capital, robots or other technologies.
- *Ease workforce transitions* – In addition to encouraging training and re-training through the public and the private sectors, government agencies may also support workers with personal counselling and improved job matching, and placement services. The youngest workers can benefit from apprenticeship programmes.
- *Anticipate the future* –This will require 'technological foresight and assessments' – eliciting knowledge from a variety of actors about the industrial growth areas that match a country's strengths to commercial opportunities.

Priorities for international cooperation

Developing countries should also be able to rely on technical and financial support through international cooperation and official development assistance (ODA). In particular this will be needed to:

- *Build stronger national capacities in STI* – This will mean increasing the relatively small amounts of ODA directed to STI in the least developed and low-income developing countries.
- *Smooth technology transfer* – The international community can facilitate technology transfer for locally relevant products and services. This may involve liberalizing access to trade and to technologies covered by intellectual property rights.
- *Increase women's participation* – If women are to play their full part in frontier technologies, governments and international organizations will need to encourage girls and women to study science, technology, engineering and mathematics (STEM) subjects.
- *Improve foresight and technological assessment* – The international community can support strategic 'foresight and technological assessment' initiatives to better understand the socio-economic and environmental implications of new and innovative technologies.

- *Promote inclusive debate* – Developing countries, especially the least developed countries, need to be part of international debates on how new technologies affect citizens' rights, privacy, data ownership and online security – and especially on how they can promote the SDGs. Developing country concerns need to be reflected in normative frameworks and regulatory regimes – balancing individual and collective rights, while encouraging private sector innovation.

Catching the wave

Developing countries, particularly low-income countries, cannot afford to miss this new wave of technological change. Each country will need STI policies appropriate to its stage of development. For some this will mean promoting frontier technologies, while renewing efforts to take full advantage of existing technologies to diversify their economies and upgrade traditional sectors. Others can engage more deeply with the development and adaptation of frontier technologies. But all developing countries need to prepare people and firms for a period of rapid change. Success in the twenty-first century will require a balanced approach – building a robust industrial base and promoting frontier technologies that can help deliver the 2030 Agenda and its global vision of people-centred, inclusive, and sustainable societies.

Endnotes

1 Milanovic, 2016
2 Jaumotte et al., 2013
3 Barzilay and Ben-David, 2016
4 UNESCO, 2019

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