UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

UNCTAD

EMBARGO
The contents of this Report must not be quoted or summarized in the print, broadcast or electronic media before
15 May 2018, 17:00 hours GMT

TECHNOLOGY AND INNOVATION REPORT 2018

Harnessing Frontier Technologies for Sustainable Development

OVERVIEW

UNITED NATIONS

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

UNCTAD

TECHNOLOGY AND INNOVATION REPORT 2018

Harnessing Frontier Technologies for Sustainable Development

OVERVIEW

UNITED NATIONS
New York and Geneva, 2018

United Nations Publications,
300 East 42nd Street,
New York, New York 10017,
United States of America
Email: publications@un.org
Website: un.org/publications

This publication has been edited externally.

United Nations publication issued by
the United Nations Conference on Trade and Development.

UNCTAD/TIR/2018 (Overview)

OVERVIEW

The 2030 Agenda for Sustainable Development sets ambitious global goals, demanding unprecedented actions and efforts across multiple interconnected social, economic and environmental issues. Science, technology and innovation (STI) must play a central role in the achievement of these goals. The process of creative destruction initiated by technological progress can help to transform economies and improve living standards, by increasing productivity, reducing production costs and prices, and helping to raise real wages.

Harnessing frontier technologies – combined with action to address persistent gaps among developed and developing countries in access and use of existing technologies, and to develop innovations (including non-technological and new forms of social innovation) – could be transformative in achieving the Sustainable Development Goals and producing more prosperous, sustainable, healthy and inclusive societies. They offer the prospect of solutions and opportunities for sustainable development that are better, cheaper, faster, scalable and easy to use. The extent of the developmental impact of technological advances has already been seen in the transformative effects of information and communication technologies (ICTs) in many low-income economies, while the potential to increase the environmental sustainability of development is evident in recent advances in renewable energy. However, new technologies threaten to outpace the ability of societies and policymakers to adapt to the changes they create, giving rise to widespread anxiety and ambivalence or hostility to some technological advances.

I. FEATURES AND POTENTIAL OF FRONTIER TECHNOLOGIES

The dramatically accelerating pace of development and adoption of new technologies in recent decades is likely to continue, driven by (a) the cumulative nature of technological change; (b) the exponential nature of technologies such as microchips, which have doubled in power every two years for half a century; (c) the convergence of technologies into new combinations; (d) dramatic reductions in costs; (e) the emergence of digital "platforms of platforms" – most notably the Internet; and (f) declining entry costs.

Several frontier technologies show the greatest potential to enable the achievement of the Sustainable Development Goals. **Big data** analysis can help to manage or resolve critical global issues, create new scientific breakthroughs, advance human health and improve decision-making, by providing real-time streams of information. **The Internet of Things** allows the condition and actions of connected objects and machines to be monitored and managed, and allows more effective monitoring of the natural world, animals and people. These two technologies have important applications in health care, agriculture, energy and water management and quality, as well as in monitoring development indicators to assess progress towards the Sustainable Development Goals. Governments should consider developing strategies to harness these technologies towards their development goals.

Artificial intelligence now includes capabilities in image recognition, problem solving and logical reasoning that sometimes exceed those of humans. Artificial intelligence, particularly in combination with robotics, also has the potential to transform production processes and business, especially in manufacturing. So too does 3D printing, which can allow faster and cheaper low-volume production of complex products and components, and rapid iterative prototyping of new manufactured products. In addition to offering some potential carbon savings by reducing the need to transport components, **3D printing** can offer benefits in health care, construction and education.

Extraordinary advances in **biotechnology** allow very specific gene editing for human medicine, making personalized treatments possible for certain conditions in combination with artificial intelligence and big data, as well as for genetic modification of plants and animals. **Nanotechnology** – the manufacture and use of materials at an infinitesimal scale – has important applications in water supply (water purification), energy (battery storage), agriculture (precise management of the release of agrochemicals), ICT (reducing the size of electronic components) and medicine (delivery mechanisms for medication). **Renewable energy** technologies allow the provision of electricity in remote and isolated rural areas inaccessible to centralized grid systems, while **drones** could revolutionize the delivery of supplies, enable precision agriculture and replace humans in dangerous tasks. Small-scale customized **satellites** will soon be affordable for more developing countries, businesses and universities, allowing monitoring of crops and environmental damage.

II. ECONOMIC AND SOCIETAL CHALLENGES

The relationship between technology and employment has long been controversial. Like earlier technological advances, frontier technologies can be expected to eliminate some jobs, while creating others. While the net effect on employment remains ambiguous, there are already signs of a polarization of employment between low- and high-skilled non-routine jobs, as jobs at medium skill levels have declined. There are also signs that the net impacts may be most unfavourable for women.

For most developing countries, the impact of frontier technologies on employment is likely to depend less on their technological feasibility than on their economic feasibility. Fears about short-term adverse effects of digitalization and automation on employment may be exaggerated, particularly if labour and education policies promote complementarity between skills available in the workforce and new technologies. Since the impact of technology depends on the structure of each country's economy, the impact at the national level cannot be assumed to be necessarily negative, but rather requires a balanced analysis of the net effects of technological and market forces. Thus, the future lies in workers creating economic value with machines rather than against them.

Effects on productivity are also ambiguous, as emerging technologies will by no means be universally adopted. Expert opinion is divided between those who see a secular decline in productivity, and those who see a divergence between "frontier" firms that adopt new technologies and reach historically high productivity, and other firms that lag behind. However, the interpretation of current trends is complicated by issues pertaining to the appropriateness of existing indicators to measure productivity in the new technological era.

Emerging digital technologies such as big data and the Internet of Things also give rise to important issues of citizen's rights, privacy, data ownership and online security. This highlights the need for effective institutional frameworks and regulatory regimes for data collection, use and access, to safeguard privacy and security, balancing individual and collective rights and allowing private sector innovation. Similar considerations apply to concerns about technological convergence driving simultaneous convergence in platforms, commercial interest and investments that can result in concentration of market power.

While the implications of frontier technologies remain uncertain, it is clear that they hold the potential for profound positive implications for almost every aspect of sustainable development. They also involve a potential risk of exacerbating existing economic, social and technological divides, as countries with strong existing capabilities harness new technologies for development, leaving others ever further behind.

Applying technology to the challenges of achieving the Sustainable Development Goals requires building local capacities and developing policies and an enabling environment – as well as unprecedented resource mobilization, partnerships and multilateral global collaboration – to (a) fund research and development (R&D) that is relevant to the Sustainable Development Goals; (b) build networks; (c) strengthen the global science–policy interface; (d) transfer technologies; and (e) support the development of capabilities in developing countries. Current national and international efforts are seriously inadequate for this task. Wide and persistent gaps in STI capacities, multiple digital divides and insufficient investments in STI limit the discovery, development, dissemination and absorption of technologies that could accelerate the achievement of the SDGs. Alongside resource mobilization, a scaled up and accelerated application of policies is needed to enhance innovation systems for sustainable development and spread the economic, social and environmental benefits of frontier technologies.

III. THE DIVIDE IN TECHNOLOGICAL CAPABILITIES

Capabilities are critical to countries' ability to exploit the opportunities offered by new and emerging technologies – and there is a wide gap in capabilities between developed and developing countries.

R&D expenditures in developing countries (except for the Republic of Korea, Singapore and China), remain much smaller both in absolute terms and relative to gross domestic product, than the world average . In large part, this reflects low business R&D expenditures: with the same three exceptions, business accounts for 32–38 per cent of R&D in developing countries, around half the world average of 68 per cent.

Despite significant growth since 2000 in the numbers of **researchers** in most developing regions, they are very unevenly distributed around the world, relative to population, with disproportionate numbers in Europe and North America. In 2014, there were 1,098 researchers per million people globally, but only 87.9 per million in sub-Saharan Africa, and 63.4 per million in least developed countries (LDCs).

The geographical distribution of **science, technology, engineering and mathematics (STEM) graduates** is also very unequal, with two thirds of them being in Asia – mainly in India (29.2 per cent) and China (26 per cent) – only 5.2 per cent in Latin America and less than 1 per cent in Africa. This partly reflects a share of STEM in tertiary education well above the global average in Asia, especially China.

IV. THE CRITICAL ROLE OF SKILLS TO COMPLEMENT FRONTIER TECHNOLOGIES

Research capacity, however, is only one aspect of the capabilities needed for the exploitation of new technologies. Also important are generic, core and fundamental skills that are complementary to new technologies – such as literacy, numeracy and basic academic skills – together with basic financial and entrepreneurial skills and, increasingly, basic digital and even coding skills. Internet access is also critical. Besides advanced cognitive skills, such as STEM, inherently human skills and aptitudes are also gaining increasing importance, as they are difficult for robots and machines to emulate. These include various behavioural, interpersonal and socio-emotional skills, creativity, intuition, imagination, curiosity, risk-taking, open-mindedness, logical thinking, problem-solving, decision-making, empathy and emotional intelligence, communication, persuasion and negotiation skills, networking and teamwork, and the capacity to adapt and learn new abilities.

Matching the supply of skills to rapidly evolving market needs is critical. This requires agility in education policies, and may mean transforming education and training systems, as there are signs that education institutions are not keeping pace with technological advances, giving rise to skills shortages, especially in digital technologies. While big data can play an important role, this also requires a holistic approach, with collaboration among policymakers, education and training systems, and employers.

Curricula need to be adapted to emphasize the skills that are becoming more significant. Teachers' methods also need to change to reorient education towards more practical, applied and experimental learning approaches, and the development of skills, competencies and capacities for continuous learning. Digital and online methods have an increasing role to play.

V. TECHNOLOGY AND DIGITAL GENDER DIVIDES

A key issue is the gender divide in STEM, information technology and computing. Globally, only 28 per cent of researchers were women in 2013, with still wider gender gaps in South and West Asia, and in East Asia and the Pacific. Despite increases in sub-Saharan Africa, the Arab world and parts of Asia, the proportion of women researchers in engineering and technology in most developing countries is 10–40 per cent. Women are also a steadily declining minority among graduates in computer science, and are underrepresented among STI decision makers.

Women are also seriously underrepresented in the digital sector. There is a major gender divide in mobile phone ownership, especially in South Asia, and in Internet use, especially in LDCs and sub-Saharan Africa, where the gap has widened since 2013. The gender gap in access to the Internet is now an intolerable 16.1 per cent in developing countries and 11.3 for the world a s a whole.

Access to energy is a major constraint to increasing ICT access for men and women alike, especially in rural areas. Decentralized energy systems, based on mini- or microgrids using renewable energy technologies, offer considerable potential to address this issue, particularly in LDCs, if technological, economic, financial and governance issues can be overcome.

The significant and persistent divide between countries in STI capabilities can both perpetuate existing inequalities and create new inequalities, particularly affecting LDCs. Addressing this divide will require strengthening national strategies in developing countries, as well as complementary international support measures, to enable them to harness new and emerging technologies effectively for sustainable development.

VI. HARNESSING FRONTIER TECHNOLOGIES REQUIRES ATTENTION TO THE BASICS OF STI POLICY

The overarching challenge for developing countries to reap the benefits from frontier technologies, as much as from more established ones, is to learn, adopt and disseminate knowledge and technologies to promote sustainable development. Success is dependent on the effectiveness of relevant innovation systems, which are weaker and more prone to systemic failures and structural deficiencies in developing countries. While centred on firms, innovation systems that also encompass research and education systems, government, civil society and consumers – and their effectiveness – rest on the capabilities of these various actors, the connections among them, and the enabling environment for innovation that they create.

In developing countries with nascent innovation systems, most actors need first to develop a basic capacity to learn how to adopt, assimilate and diffuse existing knowledge and technologies. This is an essential requirement for technology transfer, which is a complement to, not a substitute for, efforts to build endogenous innovation potential.

Connections among actors are equally essential, to facilitate learning, technology adoption and the development of new technologies. This requires networking and collaboration capabilities among all actors, even where there are innovation intermediaries or knowledge and technology brokers. Where the local knowledge base is underdeveloped and access to market intelligence limited, developing links with foreign firms, funders and research centres is a key step. While innovation collaboration can occur spontaneously, it often requires active facilitation by government or non-government actors, especially in areas related to social and environmental challenges.

An effective innovation system requires attention to the five key elements of innovation systems as an enabling environment:

(a) The regulatory and policy framework, which should provide a stable and predictable environment to facilitate long-term planning by firms and other innovation actors;
(b) The institutional setting and governance, which should be oriented towards incentivizing actors to invest in productive rather than rent-seeking

activities;

(c) The entrepreneurial ecosystem, which should provide flexible access to finance, through appropriate and readily accessible financial instruments, together with organizational capabilities and managerial competences;

(d) Human capital, including both the technical and managerial skills involved in innovation activities, through a strong technical and vocational education system; and

(e) Development of technical and R&D infrastructure, including ensuring affordable access to ICT and overcoming geographical, gender, generational and income digital divides.

Access to affordable financing is a major constraint to R&D, technology and innovation, especially in LDCs. Traditional financial systems have proved poorly suited to meeting the needs of innovation, particularly in the earliest stages of technology development and innovation, due to a combination of uncertainty and market failures related to asymmetric information, principal–agent problems and the limited ability of private agents to appropriate knowledge.

This has led to most Governments becoming involved, directly or indirectly, in financing R&D, technology and innovation. Tax incentives are widely used, and have generally been found to be effective, but with uncertain fiscal costs. However, successful innovation systems require a combination of public finance and development bank funding, often including grants, with private capital, market-based solutions and philanthropic financing. An important objective of STI policy is to promote the development of financing instruments appropriate to each stage of the innovation process. Useful mechanisms include matching grants for seed funding, and lending or loan guarantees by development banks in priority areas.

Intellectual property protection, particularly through patents, is an important issue for innovation. Such protection has strengthened in recent years, partly as a result of "TRIPS (trade-related intellectual property rights)-plus" provisions in free trade agreements and bilateral investment agreements. While intended to promote innovation, patent protection does not necessarily lead to better development outcomes, as most patents have been taken by foreign rather than domestic firms, limiting the scope for local innovation. Creation of low-cost research activities is generally a higher priority, and may be encouraged by a "petty patent" system,

granting less stringent protection to relatively unsophisticated innovations.
While strengthening intellectual property protection globally was intended to encourage technology transfer, particularly to LDCs, it can do so only as part of the wider indigenous innovation system, in conjunction with industrial and other policies, and with adequate local capabilities.

There are important areas of tension between intellectual property protection and the realization of the potential of frontier technologies in areas such as agriculture, health and energy, suggesting that an exclusive focus on strengthening intellectual property protection may be inappropriate. The principle of policy space for flexibility and inclusiveness is fundamental, to allow intellectual property regimes to be geared to each country's needs and capacities, through an appropriate balance between the granting of exclusive rights and the promotion of follow-on innovation by competitors.

VII. POLICY COHERENCE IS CRITICAL

To be fully effective, STI policies need to be internally consistent and fully aligned with national development plans. The former can be promoted through the design and deployment of strategies and policy instruments at the most appropriate level, while the latter requires a "whole-of-government" perspective, facilitating cooperation across ministries and other public bodies in different fields of policy. Coherence is needed across policy areas such as industrial policies and those on STI, foreign direct investment (FDI), trade, education and competition, along with macroeconomic policies, including monetary policies.

Key steps towards building synergies between STI policy and overall development strategies include:

(a) Conducting a critical review of the innovation system and STI policy;
(b) Building a shared vision and choosing strategic priority areas for STI policy;
(c) Facilitating strategic partnerships;
(d) Designing a long-term STI strategy and policy road map; and
(e) Establishing monitoring and evaluation systems and nourishing policy learning.

Establishing advanced capabilities in policy design and the implementation this requires is a priority area for capacity-building.

VIII. REDIRECTING INNOVATION TOWARDS INCLUSIVENESS AND SUSTAINABILITY

Addressing the challenges of inclusiveness and sustainability in the context of the 2030 Agenda for Sustainable Development requires (a) broadening the strategic focus of STI policy to integrate societal challenges at its core; (b) internalizing the direct and indirect contributions of innovations to economic, social and environmental aspects of sustainable development; and (c) fostering transformative innovations with the potential to supplant unsustainable practices and systems.

Concerns about the employment implications of frontier technologies have fuelled a growing debate about the need to adapt the social contract to a new context of rapid change in technology, but also in key parameters of the social, cultural and political environment. Two themes have emerged consistently in this debate: (a) lifelong learning, through skills updating and skills upgrading, can help to match the supply of skills to match demand, while allowing workers to adapt to a rapidly changing labour market; and (b) universal basic income (UBI), periodic cash payments made unconditionally to all members of society, has been proposed as a means to provide financial security both to those unable to adapt successfully to changing skills needs and to potential innovators. A number of (mostly local) experiments are underway, and the preliminary results are encouraging; but the considerable fiscal cost remains an obstacle.

Beyond these foundations of STI policy, several new concepts and policy approaches could further strengthen the contribution of technological change to the 2030 Agenda for Sustainable Development.

IX. LEAPFROGGING: LOOK BEFORE YOU LEAP?

New and emerging technologies open opportunities for **leapfrogging** – bypassing intermediate stages of technology through which countries have historically passed during the development process. For most developing countries, however, limited capabilities mean that such opportunities arise primarily in the form of adoption of existing technologies – exemplified by the transformative effects of mobile telephony in African countries – rather than the development of new technologies. While the case of the mobile telecom sector seems difficult to replicate, there is potential for leapfrogging in the energy sector through the development of decentralized renewable energy systems. This may provide a cost-effective means of accelerating sustainable development. Innovation policies can support such a process, if backed by finance, investment and technology transfer, but important technological, economic, financial and governance obstacles need to be overcome, particularly in LDCs.

X. NEW APPROACHES TO INNOVATION

At the other end of the spectrum, **new concepts of innovation** are emerging that focus on inclusiveness, including pro-poor, inclusive, frugal, grass-roots and social innovation. Policies to support such approaches can help extend the benefits of innovation to previously excluded groups, promote informal innovation by marginalized groups, include local communities in the innovation processes, and promote innovations in social relationships, practices and structures to address social needs and improve well-being.

Smart specialization is an explicitly experimental variation of traditional vertical industrial policies at the regional level, based on systematizing and responding to the information generated by positive and negative policy results through a process of entrepreneurial discovery. Smart specialization involves the development of a set of transformative activities – collections of innovation capacities and actions oriented towards a particular structural change – aimed at focusing R&D, partnerships and the supply of public goods on particular opportunities, while facilitating collective actions among innovation actors. A key feature is the selection of priorities at the level of the transformative activities, rather than the sector or firm level, through transparent, decentralized and evidence-based interaction between the public and private sectors.

Platforms for economic discovery (PEDs) are based on the fundamentally economic, rather than technological, nature of innovation – the process of translating technological inputs into products, processes and services, and discovering whether it will be adopted, at what price, and through what kind of business model. This is insufficiently recognized, skewing policy and international support for innovation towards scientific and technological aspects. This report proposes an international cooperation effort to support the establishment of local and regional PEDs, focusing on smart specialization priorities, to provide entrepreneurs with the capacities, capabilities and services needed for innovation, to ensure a sufficient rate of return to economic discovery. Such an effort would provide a practical avenue for development partners to refocus and strengthen international cooperation for innovation.

Incubators, accelerators and technology parks can play a useful role as complements to smart specialization and PEDs. Their success depends on actively fostering the emergence of competitive start-ups and facilitating links between companies inside and outside of incubators.

XI. SHAPING RESEARCH COLLABORATION TO ADDRESS THE SUSTAINABLE DEVELOPMENT GOALS

Global collaboration in scientific research has grown considerably over recent decades, opening new opportunities for the combination of the most advanced scientific capabilities, with detailed local knowledge in key areas of sustainable development. The capacities of many developing countries to participate in such collaboration have increased considerably. To direct such networks firmly towards achievement of the Sustainable Development Goals, Governments need to move beyond funding and managing R&D to influencing networks, which requires an understanding of their formation, organization, norms, dynamics, motivations and internal control mechanisms. Key interventions include (a) funding; (b) convening international events on particular aspects of the Sustainable Development Goals; (c) supplementing research grants with targeted support for travel and communications; (d) establishing prizes and awards; (e) establishing national platforms for collaborators on issues related to the Sustainable Development Goals; and (f) framing local problems in such a way as to attract international research attention. Development impact can be enhanced by mapping existing scientific knowledge and current research against local needs, to target research and avoid redundancy, and by the use of gap analysis to develop sufficient absorptive capacity to retain knowledge locally.

XII. CHANGES IN THE FUNDING OF INNOVATION

Changes in financing also offer new opportunities for funding innovation. Policies can usefully support the emergence of **venture capital financing**, where the basic conditions exist (notably significant high-tech activity and scope for the creation of a critical mass of start-ups), and the development of active **angel investment** networks, including through support to upgrading of entrepreneurs. While the absence of active stock exchanges is an obstacle to developing venture capital, this can be averted by access to initial public offerings on foreign stock markets or regional exchanges, or by establishing secondary exchanges for small and medium-sized enterprise (SME) listings (thus making the investment in venture capital more liquid and hence more attractive), which can also create additional channels for risk financing.

Impact investment also merits further investigation as a potential avenue for funding STI for the Sustainable Development Goals, given its orientation towards social and environmental objectives, although it is currently focused mainly on developed countries and on mature private companies. **Crowdfunding**, too, offers potential, but (a) as with impact investment, currently exists mainly in developed countries; (b) is focused mainly on social and artistic causes and real estate activities; (c) largely takes the form of donations, rewards and preselling; and (d) is relatively small in scale. Before promoting crowdfunding, developing country Governments should consider the risks involved and establish appropriate regulatory positions, particularly for equity crowdfunding.

Innovation and technology funds financed by the public sector, international donors, development banks or the private sector have become an important instrument for innovation funding in developing countries. They have the advantage of being relatively fast to introduce, flexible in design and operation, and able to target particular industries, activities or technologies and support strategic goals, making them complementary to smart specialization and PEDs. However, their success relies in part on the strength of the innovation system as well as on their design.

All in all, new approaches offer some potential to build on the broader foundations of STI policy to promote innovation oriented towards sustainable development. But realizing the almost unlimited potential of technology and innovation to contribute to the 2030 Agenda for Sustainable Development will require action at the national and global levels to match the extraordinary ambition of the Sustainable Development Goals themselves.

Printed at United Nations, Geneva – 1807605 **(E)** – April 2018 – 2,622 – **UNCTAD/TIR/2018 (Overview)**