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Presentation of reports by the secretariat: Emerging technologies, competitiveness and regional integration

Harnessing emerging technologies for competitiveness and regional integration

I. Introduction

1. The work on technology and innovation is undertaken by the Green Economy, Innovation and Technology Section in the Technology Climate Change and Natural Resources Division of the Economic Commission for Africa (ECA). The overall objective is to support member States to harness science, technology and innovation and green economy to meet their development goals. This is achieved by undertaking rigorous policy analysis research, pilot projects, advocacy and consensus building activities as well as contributing original data and proposals to inform policymaking.

2. Against this backdrop, the present thematic report provides an outlook of the potential of emerging technologies in helping to achieve the Sustainable Development Goals in Africa, improving the competitiveness of the private and public sectors, and in deepening regional integration. The focus is on digital technologies, with greater emphasis on cloud computing and nanotechnology (highlighting the extraordinary growth registered in science, technology and industry), the potential economic, social and environmental contributions that could be gained and the key role that these technologies can play to drive forward regional integration in Africa.

3. The thematic report presents some of the ongoing work being undertaken by ECA regarding the application of emerging technologies in Africa. Sections II and III provides the background and objective of the report, respectively. Section IV contains an overview of emerging technologies and section V presents the current state of development in Africa and its participation in emerging technologies. Section VI explores the regional perspective of emerging technologies. Section VII outlines the conclusions and ongoing work of ECA, and section VIII presents some proposed issues for discussion.

II. Background

4. Science, technology and innovation are emphasized in Agenda 2063 of the African Union as critical enablers for African countries to achieve middle-income countries with manufacturing accounting for 50 per cent of gross domestic product

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(GDP) and high tech exports constituting at least 50 per cent of manufactured exports, and its people enjoying a high standard of living and quality of life for all citizens and its natural resources managed in a sustainable manner. Accordingly, technology has been singled out as a core lever of development and as a means of implementing the 2030 Agenda for Sustainable Development and Agenda 2063.

5. In particular, emerging technologies offer developing countries unique opportunities to catch up with leading nations and improve the living standards in many ways. They disrupt existing business models and systems (for example, wireless technologies), open up new technological niches (mobile money) that allow less developed countries to leapfrog old technologies, and reduce entry barriers through co-learning by both the developing and developed countries alike (governance of cryptocurrencies, taxing digital firms). The less developed countries, however, face the challenge of limited intellectual assets, financial resources and key infrastructure to acquire, learn, use and further upgrade new and emerging technologies.

6. It is for this reason that the science, technology and innovation strategy for Africa 2024 (STISA-2024) was adopted by the Heads of State and Government as the continental blueprint to guide science, technology and innovation development. Among others, STISA-2024 calls for member States to build technical competences, invest in science, technology and innovation infrastructure, promote innovation and entrepreneurship and to put in place national and regional science, technology and innovation policies. STISA-2024 also renewed the call for member States to invest at least 1 per cent of their GDP in research and development. These targets are also restated in the 2030 Agenda for Sustainable Development and Agenda 2063, based on the recognition that these capabilities are prerequisites that enable technology to serve as effective means of implementation.

7. Notwithstanding the above intentions, the region's science, technology and innovation capability remains small and its performance in technology use and ownership is uneven.[1] For example, research and development expenditure is estimated at 0.5 per cent of GDP with a number of countries registering a decline (such as Uganda), some remaining almost unchanged (such as in Ghana, Malawi, Namibia and Senegal) and others registering growth (for example, in Egypt, Ethiopia, Kenya and Mali). Key sources of research and development funding, however, have remained Governments and external partners, with the exception of South Africa, where the business sector accounts for 40 per cent as a source of research and development funding. In other words, both the public and private sectors are not investing enough resources in this area.

8. The technological base in Africa is even smaller than its research and development system. Africa accounts for 2 per cent of the world's researchers in research and development and 1 per cent of the global research and development expenditure, but it accounts for only 0.3 per cent of high technology exports and 0.2 per cent of the global payment for intellectual property. This trend is of great concern at a time when knowledge-intensive exports now account for nearly half of total global trade. It also undermines the continent's ability to diversify and offer a wide variety of products and services that could bring about intra-African trade, and encourage regional partnerships and formation of strategic alliances across borders. Together, limited research and development and a narrow technology base have a major impact on the access and use of emerging technologies and on innovations, even in traditional sectors such as agriculture and health.

9. This has significant implications for the region's participation in the global market for emerging technologies, competitiveness of the African private sector and in terms of deepening regional integration. For example, there have been several pockets of brilliance throughout Africa that have brought about computers, tablets, mobile phones and software or cars, but the majority have failed to keep up with rapid

[1] ECA, *Towards achieving the African Union's recommendations of expenditure of 1% of GDP on research and development*, Policy Brief No. ECA/18/004 (Addis Ababa, 2018).

technological changes. In short, by the time a mobile phone is launched, the producer is researching and developing the designs and other component of the next generation of the mobile phone. The same is seen in the automobile industry, household electronics, energy and pharmaceutical products. The region's ability to compete will depend on the strength of its technical competencies, quality of its research and innovation infrastructure, and a critical mass of its entrepreneurial and innovative talent.

III. Objective

10. The overall objective of the present report is to highlight the potential technological, economic and social contributions of emerging technologies in Africa and how African countries are faring in harnessing emerging technologies to meet their development aspirations. It is also intended to stimulate dialogues on: key attributes and benefits of emerging technologies; existing policy and governance arrangements regarding whether they are "fit for purpose" in a rapidly changing world; and how regional integration can help to bring about investment in key infrastructure and competencies required to unlock the full potential of emerging technologies. The outcomes will inform the work of ECA and member States.

IV. Emerging technologies

11. Emerging technologies are not always new technologies but may include new applications of existing technologies (such as mobile money, renewable energies) or a result on the convergence of technologies or disciplines (for example, bioinformatics, artificial intelligence, electric vehicles). For this reason, emerging technologies may be termed as transformative technologies or frontier technologies and they may "encompass an array of new materials, products, applications, processes and business models, [that] are interdependent, interconnected and mutually reinforcing".[2]

12. Emerging technologies share a number of common attributes that are associated with the ability to transform or disrupt current industries; reallocate economic, social and environmental value; and alter how people live and work, among others. For this reason, emerging technologies can be viewed as follows:

(a) Discrete – they stealthily diffuse and transform society (nanotechnology and digitally enabled products have quietly diffused to all sectors);

(b) Pervasive – they affect and effect change in all sectors (artificial intelligence in health, agriculture, transport);

(c) Enablers – powers other technologies to achieve higher levels of productivity (digital power biology in bioinformatics; nanotechnology power in electronics);

(d) Drivers of innovations – open up endless opportunities for innovations (mobile technologies spurred endless numbers of applications in almost all sectors).

13. In 2016, the Organization for Economic Cooperation and Development (OECD) identified around 40 key technologies that fall into four main categories – biotechnologies, advanced materials, digital technologies, and energy and environment (see table 1). A number of the technologies, such as drones in energy and environment category, will not function efficiently without the digital technologies and advanced materials of which they are made. It highlights the interdependence and convergence of most of the key technologies. As box 1 shows, drones have found a different application in Africa from those in developed countries.

[2] E/2018/50/Rev.1. ST/ESA/370 (Executive summary).

Box 1

Drones for Africa

Africa is an expansive and rural continent with breathtaking landscapes and magnificent mountains and water bodies. With underdeveloped transport infrastructure, drones or unmanned aerial vehicles are a timely technology that are delivering medical supplies in Rwanda and Ghana at a small fraction of the time, planting Acacia seeds from the sky to tame soil erosion in South Sudan, fighting poaching in South Africa to prevent soil erosion, traffic monitoring in Kenya and city planning in Namibia. The unmanned aerial vehicles are finding civic and humanitarian applications.

In terms of capacity development, organizations such as Flying Labs (see, https://flyinglabs.org) are working with knowledge centres in 13 countries in Africa, 6 in Asia, 5 in the Americas and 1 in Spain. The organization works with universities and other stakeholders on educating children and young people on coding, mapping, analysis and piloting; promoting safe and responsible use of the technology; creating ecosystems for robotics; and helping to inform domestic legislation and regulations. A similar effort is being undertaken by African Drone (see, https://africandrone.org).

Table 1
Top 40 key technologies

Biotechnologies Personalized medicine, bioinformatics, health monitoring technology, medical and bioimaging, stem cells, regenerative medicine and tissue engineering, biocatalysis, synthetic biology, biochips and biosensors.	**Advanced materials** Nanomaterial, functional materials, nanodevices, additive manufacturing, carbon nanotubes and graphene.
Digital technologies Cloud computing, blockchain, photonics and light technologies, modelling simulation and gaming, grid computing, robotics, big data, analytics, the Internet of Things, artificial intelligence and quantum computing.	**Energy and environment** Smart grids, autonomous vehicles, micro and nanosatellites, drones, precision agriculture, biofuels, power microgeneration, advanced energy storage technologies, fuel cells, photovoltaics, hydrogen energy, marine and tidal power technologies, carbon capture and storage, electric vehicles and wind turbine technologies.

Source: OECD Science, Technology and Innovation Outlook 2016 (Paris, 2016).

14. In order to effectively benefit from these emerging technologies, there is a need to provide information on the nature and state of scientific, technological and industrial developments, the opportunities and challenges these technologies present, and the factors driving their growth or lack thereof. Such information can help countries to put in place appropriate measures, policies and regulations that enable individuals, firms and institutions to acquire, master, develop and use emerging technologies in a safe, inclusive and responsible manner. This was reaffirmed in the "Report of the Conference of Ministers on the work of its fifty-second session" in which they called upon ECA to "help member States to replicate good practices in digital economy" and upon member States to "build their human and technological capacity" and "formulate integrated plans for the development of the digital and green economy".[3]

[3] Fifty-second session of the Economic Commission for Africa Conference of African Ministers of Finance, Planning and Economic Development, Marrakech, Morocco, 25 and 26 March 2019.

V. African participation in emerging technologies

15. There is significant interest in the role of emerging technologies in spearheading the continent's transformation and in achieving the goals of the 2030 Agenda for Sustainable Development. The following subsections provides a discussion on two of the broad categories of emerging technologies – digital technologies and advanced materials with a focus on nanotechnology.

A. Digital technologies

16. Digital technologies are transforming every aspect of society and provides African countries with the opportunity of technological catch-up. For example, Africa is now home to 11.5 per cent of the world's total Internet users and its Internet penetration rate is growing faster than the world average. In other words, there are now more Internet users in Africa than in North America. Similarly, the number of mobile phone subscribers in Africa has grown from around 544 million in 2010 to roughly 1.2 billion in 2018.[4] With some 550 million unique mobile subscribers, Africa has more unique mobile phone users than the combined population of the European Union member countries, or North Africa or South America. Sub-Saharan Africa alone has a mobile economy of $144 billion, accounting for approximately 8.6 per cent in 2018.[5]

17. From this perspective, Africa is doing relatively well and even leading in some areas, such as the number of active mobile money accounts (45.6 per cent of the world share), beating South Asia (33 per cent) and East Asia and the Pacific (11.3 per cent). The encouraging cases of M-Pesa and Zoona have attracted significant interest from innovators, entrepreneurs, investors and political leaders to drive the adoption and growth of mobile services and of innovation hubs on the continent.

18. There are now some 618 technology hubs in Africa packed with young people working mainly on digital solutions for agriculture, health, education, finance and a multitude of other concerns. This is a 40 per cent growth on the 442 figure of 2018. A number of the tech hubs are now supported by corporate and global digital firms such as the Mobile telecommunication company (MTN), Google, IBM and Orange, alongside regional networks (for example, South African Innovation Support based in Namibia).

19. Africa is yet to fully capture the dividend of the digital economy. For example, the global Internet traffic has grown from 2,000 gigabit (GB) per second in 2007 to a massive 46,000 GB per second.[6] The region's share of the global Internet traffic is less than 1 per cent. Poor Internet infrastructure, the cost of the Internet and the risks and costs associated with increased use of the Internet in business, are some of the factors that may be discouraging African firms and institutions from investing in increased use of digital solutions.

20. The digital economy is unpinned by several key technologies, such as artificial intelligent, machine learning, cloud computing (see box 2), blockchain, the Internet of Things, robotics and three-dimensional (3D) printing. These are areas in which the continent's capabilities are still emerging. For example, the estimates given by the United Nations Conference on Trade and Development in their 2019 report, suggest that Africa and Latin America account for a combined share of 1 per cent of the world's 70 largest digital platforms, while China and the United States of America account for 90 per cent. A similar trend is observed in terms of patents on blockchain,

[4] GSMA, "618 active tech hubs: the backbone of Africa's tech ecosystem", 10 July 2019.

[5] GSMA, "The mobile economy, Sub-Saharan Africa 2019". Available at https://www.gsma.com/r/mobileeconomy/sub-saharan-africa/.

[6] United Nations Conference on Trade and Development, *Global Digital Report 2019. Value creation and capture: implications for developing countries* (Geneva, 2019).

global spending on the Internet of Things, and on the global market of commercial cloud computing.[7]

21. While Africa is doing well in terms of the growth rates of Internet and mobile user numbers, the continent's stake in digital technology ownership, digital market share and top digital platforms remains small. Africa needs to build its capacity not just to use but also to own technologies and support the development of businesses to realize the potential offered by the digital economy. Digital transformation is not just about investment in technology but also in the associated skills, organizational change, new systems and new business models to achieve higher productivity. It is these complementary investments that may be high for many small and medium-sized firms in Africa.

22. For example, Jumia Technologies – dubbed Africa's Amazon – became the first African digital technology firm to be listed on the New York Stock Exchange in April 2019 and one of the few firms worth more than $1 billion. Such firms have invested more in the skills and organizational arrangements that enable them to operate as a megastore and a delivery service. Similarly, DHL launched the Africa-eShop that allows individuals and firms in Africa to buy items from more than 200 major shops in the United States and the United Kingdom online to be shipped directly to their homes. In this case, DHL is integrating e-commerce services and its expertise and experience in delivery of shipments anywhere in the world to run its Africa-eShop.

23. While the potential of digital technology is huge, Governments may wish to support research and development, technology acquisition and infrastructure development in a bid to foster and enhance inclusive growth of the digital economy.

Box 2

Cloud computing

One of the technologies that anchors the digital economy is cloud computing because more and more individuals, firms and institutions generate large volumes of data that their systems cannot store, process and use. At present, public cloud services are expected to grow at 17.5 per cent in 2019 from $182.4 billion to $214.3 billion globally, and is projected to hit $331.2 billion in 2022.[8] Some of the top firms (such as Amazon, Google and Microsoft) are making massive investment in cloud services covering applications, infrastructure management, security and business processes, among others.

There is excitement that growth in demand for cloud computing in Africa will attract several global services providers to enter the African market. Top banks, retailers, hotels and government services on the continent are already using cloud services outside Africa and the market is growing at approximately 30 per cent annually, with revenue expected to hit $4 billion by 2023 (1.2 per cent of the global market). The recent launches of Microsoft Azure data centres and Huawei African cloud (both in Johannesburg and Cape Town) in 2019 and the announced launch of Amazon Web Services in 2020 are all indicative that the African market is ripe for cloud services and set to grow faster.

Source: Author, based on several sources (2019).

24. Several major challenges may be hindering the continent's chances to claim the benefits of the digital economy fully. Poor support infrastructure, costs of digital services, limited human capital with the skills necessary to do the work, inadequate incentives and a suboptimal regulatory environment are among some of the top challenges facing African countries. In addition, the investment and institutional

[7] Ibid.

[8] Gartner, "Gartner forecasts worldwide public cloud revenue to grow 17.5 per cent in 2019", 2 April 2019.

capacity needed to acquire, master, develop, use and promote innovations in digital technologies are still emerging.

25. There are also fears that the digital economy will result in jobs losses, reduced foreign direct investment and revenue losses. For example, countries can rely on expertise and infrastructure anywhere in the world or increased automation (or both), which reduce the need for workers. While employment in the information and communications technology sector has grown, there are fears that job losses will occur in sectors as far as agriculture, manufacturing and health.

26. Differences in labour costs between developed and developing countries could be offset by automation, leading to reduced flows of efficiency-seeking foreign direct investment. Considering that foreign direct investment has been one of the channels for diffusing advanced technologies and global good practices world-wide, reduction in foreign direct investment could lead to widening knowledge, technology and income inequalities among rich and poor countries.

27. Taxation of digital firms remains a challenge. Firms such as Jumia and Amazon can help African businesses anywhere to sell to clients everywhere. It is also empowering individuals to undertake work anywhere, irrespective of where they live. The digital economy is redefining the workplace and where value is added. Tax regulations need to catch up in terms of the digital economy, but recent developments in some European countries (such as France and the United Kingdom of Great Britain and Northern Ireland) to tax the digital economy may provide examples for African countries.

B. Advanced materials with a focus on nanotechnology[9]

28. Like digital technologies, nanotechnology is a general purpose and infrastructure platform technology that is driving developments in other technologies and sectors of the economy. For example, nanotechnology is behind the information and communications technology revolution – powering the development of nanoelectronics – the extremely miniaturized chips and transistors packed into the fast processors and development of hard drives with unlimited processing and storage capacity.[10] Nanotechnology is accelerating biotechnology development and is also an integral part of advanced manufacturing.

29. It is for the above reasons that nanotechnology has been termed “pervasive”, “enabler” and “key driver” of the next industrial revolution. The nanotechnology value chain (see table 2) ranges from the tools needed to manipulate matter at nanoscale to the finished products that incorporate nanomaterial. It is nearly impossible to avoid products that include some aspects of nanotechnology in the marketplace – it is found in washing machines and washing detergents, cosmetics, medicines, food packaging, electronic products, computers and mobile phones, among others.

[9] This section is primarily based on the outcome of the Expert Group Meeting on “An African Nanotechnology future? Policies and Regulations”.

[10] National Academies of Sciences, Engineering and Medicine, *Triennial Review of the National Nanotechnology Initiative* (Washington, D.C., The National Academies Press, 2016).

Table 2
Nanotechnology industry value chain

	Nanotools	*Nanomaterials*	*Nano-intermediates*	*Nano-enabled*
Description	Equipment and software for visualizing, manipulating and modelling	Unprocessed forms of nanoscale structures	Intermediate products with nanoscale features	Finished goods incorporating nanotechnology
Example	Nanoimprint lithography equipment	Nanoparticles, quantum dots and nanotubes	Memory and logic chips, superconducting wires, fabrics	Electronic devices, medicine, plastics, cars

Source: *Michael Berger*, Debunking the trillion-dollar nanotechnology market size hype, Nanowerk; see www.nanowerk.com/spotlight/spotid=1792.php.

30. OECD defined nanotechnology as "the understanding of processes and phenomena and the application of science and technology to organisms, organic and inorganic materials, as well as parts, products and models thereof, at the nanometre-scale (but not exclusively below 100 nanometres) in one or more dimensions, where the onset of size-dependent phenomena usually enables novel applications."[11] Nanotechnology includes nanomaterials, nanoelectronics, nanophotonics, nanomedicine, nanomagnetics and nanomechanics.

31. At present, nanotechnology is making remote health monitoring of patients possible through wearable sensors and smart textiles, detection of diseases through portable lab-on-a-chip, and it is extending the shelf-life of food through nanotechnology-enabled packaging that kill bacteria. Research has been undertaken by Majumder, Mondal and Deen (2017), Vu and Kim (2018) and Sharma, and others (2017) on these nanotechnologies. The dream of nanotechnology-enabled products is being realized not just in high-tech sectors (electronics) but also in low and medium-tech industries (such as ceramic tiles that are easy to clean, textiles that repel dirt and cleaning materials that pick up dust).

32. In terms of market size, revenue from nanotechnology enabled-products increased from $850 million in 2012 to 1.6 trillion in 2014 (a growth of approximately 90 per cent). The strong growth in the nanotechnology market is partly driven by increasing investment in research and development that is bringing new industrial applications at a rapid pace. This can be seen from the growth in nanotechnology-related science publications from 13,000 in 1997 to 154,000 in 2016 (a 14 per cent annual growth rate), with 141,170 patent applications filed in the United States Patent and Trademark Office (USPTO) and the European Patent Organization (EPO) between 2001 and 2017. Figure I shows the top ten African countries that produce articles relating to nanotechnology).

33. Although nanotechnology has had an impact on all aspects of life, its greater impact is likely to be on Sustainable Development Goal 2 (food), Goal 3 (health), Goal 7 (energy), Goal 8 (employment), Goal 9 (infrastructures/innovation), Goal 11 (cities) and Goal 12 (responsible consumption). It is in these areas that most of the private investment in research and development is targeted, and in which patents are granted and high-impact technologies by applications are concentrated. The impact that nanotechnology has on other Sustainable Development Goals will be equally important but likely to be indirect unless the continent invests in key nanotechnology applications of its interest (for example, water, climate change and peace and security).

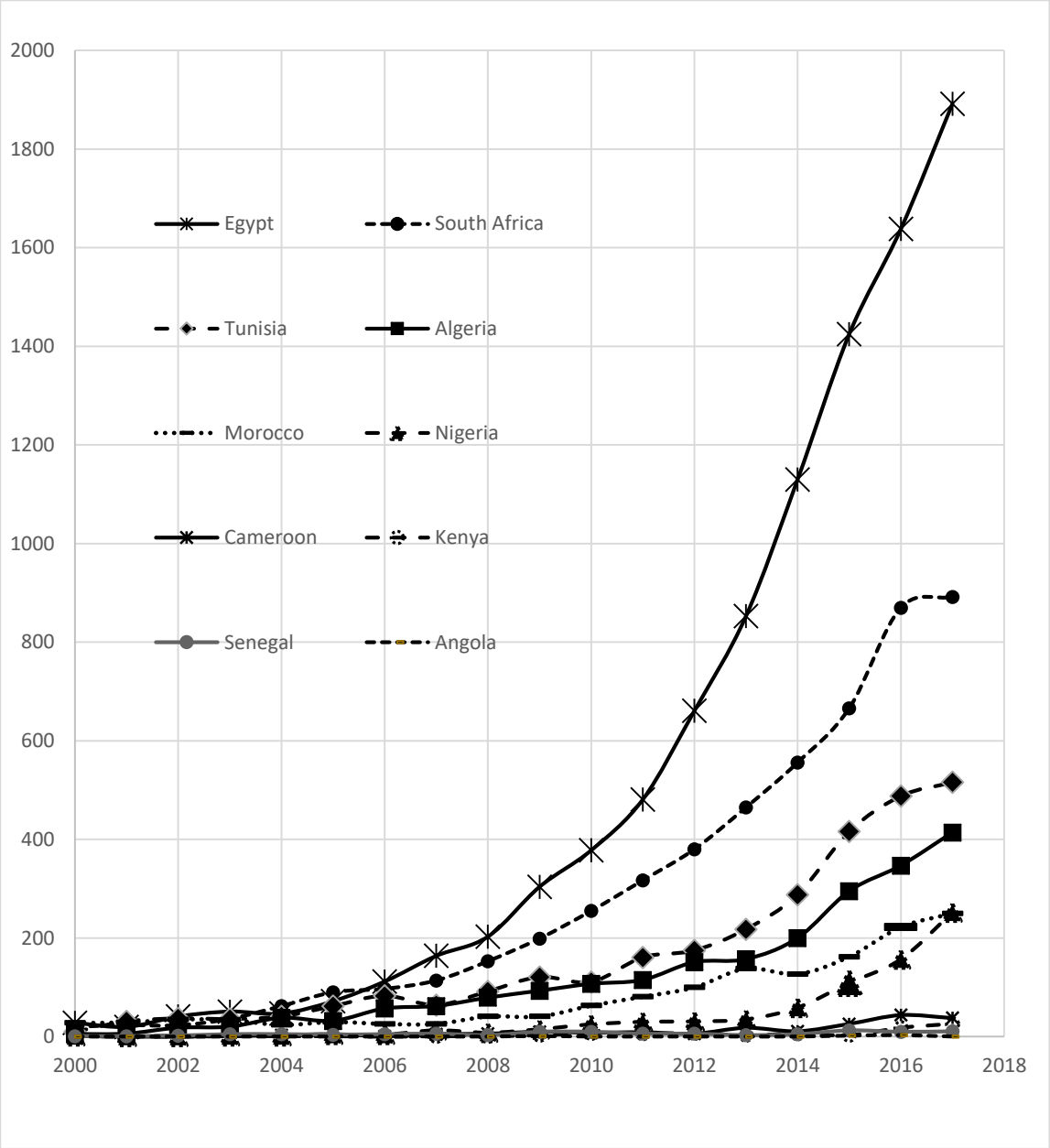
34. A number of developing countries (such as China, Iran and Saudi Arabia) are among the top research and development performing countries in nanotechnology. The United States remain the largest contributor, followed by Korea, Japan and Germany, respectively. Between 2010 and 2017, the fastest growth rate was posted

[11] *OECD Science, Technology and Innovation Outlook 2016* (Paris, 2016).

by Saudi Arabia – from 8 to 167 patent applications during that period. In comparison, South Africa had a combined 94 patent applications for nanotechnology-related inventions filed in USPTO and in EPO between 2001 and 2017. Even technologically advanced African countries are lagging behind their less technologically advanced peers. In sum, the continent seems to be lagging behind.

Figure I

Nanotechnology articles by the top 10 African countries



Source: Information taken from Statnano database (2019).

35. Nanotechnology is already in use in Africa. Frontrunners such as South Africa have developed strategies and have built the basic infrastructure to harness nanotechnology for industrial (processing, bioprocessing and manufacturing) and social (clean water, energy and primary healthcare) sectors. In Uganda, a nanotechnology Centre of Excellence at Makerere University funded by the World Banks is applying nanotechnology to herbal medicine and mineral processing for healthcare needs. Firms in Ethiopia and the United Republic of Tanzania are exploiting nanofilters to provide safe clean drinking water without the use of large

amounts of chemicals and huge energy. African mines are finding use of nanosensors in monitoring high temperatures.

VI. Regional perspective to harness emerging technologies

36. In the context of the emerging Africa Continental Free Trade Area, and in the rise of regional science, technology and innovations activities of several regional economic commissions, steps to utilize regional blocks to serve as vehicles for developing common strategies, research infrastructure, innovation spaces and industrial application of emerging technologies may be helpful in tackling skills, and research and development infrastructure challenges. At present, African countries are collaborating more with partners outside the continent than their neighbours within.

37. A large part of the emerging technologies requires huge investment in research and development infrastructure in various disciplines, which most African countries cannot afford. Accordingly, developing regional innovation systems and platforms could alleviate financial resources constraints and bring together the limited expertise in a wide area of technologies to interact and reinforce each other. For example, expertise in neuroscience in one country will be helpful in informing design and development of artificial intelligence in another country, which in turn, can help to further neuroscience research. Such regional innovation systems could also help to bridge gaps in knowledge and expertise, open access to key resources (such as minerals, funding and networks) and create the critical mass needed to undertake research in knowledge-intensive multidisciplinary fields.

38. Harmonization of regulations and practices could be dealt with at the regional level. Environmental, safety, labour, competition, standards and pricing could also be developed at the regional level and adapted to national realities. While these are emerging in fields such as drugs, telecommunications and cybercrime and cybersecurity, few efforts have been made to develop similar approaches for emerging technologies. For example, of the 39 participating member countries in the Technical Committees ISO/TC 229 Nanotechnologies of the International Organization for Standardization that develops nanotechnology standards, Africa is represented by one country (South Africa) while Asia is represented by seven countries and Latin America by three. Another five African countries (Egypt, Ethiopia, Kenya, Morocco and Zambia) serve as observer members.

39. Given that most of the gains of emerging technologies will be captured at individual and firm levels, regional efforts to develop minimum acceptable standards and regulations could increase the pace of technological developments, attract investment in emerging technologies and deepen regional integration. Evidence from the growth of mobile phones suggests such efforts to reduce prices, expand the market and encourage technology uptake by individuals, institutions and firms.

40. Measures to create a platform or inventory of research facilities and experts involved in emerging technologies could enhance intraregional collaboration as well as encourage more countries to harness emerging technologies to meet their development goals. Intra-African collaboration could also be viewed as science diplomacy – enabling people and businesses to get a better understanding of the challenges and opportunities beyond their national borders – these could boost innovation and regional integration.

VII. Conclusion

41. During the past years, ECA has undertaken rigorous policy research and has provided policy advice to member States on several emerging technologies, such as blockchain, artificial intelligence and nanotechnology. Emerging technologies offer Africa the opportunity to facilitate deeper regional integration. Digitalization of tax authorities with integrated payment and processing systems (such as E-Visa) are

reducing the amount of time needed to process goods and people at borders, and increasing revenue collections by eliminating fraud through direct electronic tax payments, among others. In addition, labour does not need to cross borders to provide value added services (such as cloud computing and digital infrastructure management and protection) or participate in innovation and technology upgrading or data analysis.

Recommendations

(a) At present, ECA is looking at the applications and implications of three emerging technologies in health and transport in Africa to guide policy development. These sectors are significantly being transformed by emerging digital, energy, nanotechnology and biotechnologies;

(b) ECA will undertake assessments to identify country needs for early warning systems as a major component of building resilience to weather and climate impacts. ECA has worked with the Governments of Cabo Verde, Mauritius and Seychelles to install high-resolution numerical weather prediction systems to improve the early warning capabilities of the Islands Hydrological and Meteorological agencies. ECA has also provided support to metrological agencies in Africa on the installation of automated weather stations (for example, in Ethiopia, Rwanda and Senegal);

(c) ECA will continue to work with the Carnegie Climate Governance Initiative (C2G) to explore options for supporting the development of appropriate policy and regulatory instruments for Carbon Capture, Use and Storage technologies in Africa. Carbon Capture, use and storage is a key approach to achieving the 1.5 degrees' target of the Paris Agreement. To date, African participation in the process has been minimal. Innovations in this field are likely to proceed without an appropriate policy and regulatory environment on the continent.

VIII. Issues for discussion

(a) What are the policy challenges facing emerging technologies and how best can they be managed? Should countries pursue individual technology policies or provide an integrated emerging technologies policies and strategies?

(b) What are the appropriate policy instruments likely to deliver development gains that are inclusive and equitable, taking into account the needs of small and medium firms, women and young people?

(c) How can Africa enhance the business environment to encourage businesses to invest in emerging technologies and realize productivity gains?

(d) What are the best approaches to strengthen and leverage intra-Africa cooperation and collaboration in emerging technologies?

(e) What skills and competencies are needed to prepare young African people and women for future jobs? What are the existing and emerging good practices from which Africa can learn?

(f) What are the key social and regulatory challenges that emerging technologies present in Africa? What needs to be done to minimize their impacts?