Draft Report

Africa Regional Science, Technology and Innovation Forum 2021

On

"Harnessing Emerging Technologies: the cases of Artificial Intelligence and Nanotechnology"

1. Introduction

The global pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) of 2019 (the disease commonly referred to as COVID-19) has highlighted the importance of technology and innovation in developed countries. Technology has enabled researchers and firms to work at unprecedented speeds to decode the organism's genetic code in weeks[1], design testing, monitoring and patient management devices or tools, and bring to market several novel vaccines in about a year. Similarly, digital technologies have transformed how people work, interact and access services. The demand for science to make informed decisions and actions to manage the COVID-19 pandemic was high in both developed and developing countries alike[2]. The ability of countries to acquire, generate, use, and upgrade scientific knowledge and technology in general, or experiment with new and emerging innovative solutions depends on their human, institutional, and financial capabilities.

It is against this backdrop that the African Science Technology and Innovation Strategy for Africa 2024 (STISA 2024) was adopted by the Heads of Government and States as the continental blueprint to guide STI development. Among others, STISA 2024 calls on member States to build the technical competences, invest in STI infrastructure, promote innovation and entrepreneurship and put in place national and regional STI policies. STISA 2024 also renewed the call on member States to invest at least 1% of the gross domestic product (GDP) in research and development (R&D). These targets are also restated in the 2030 Agenda for Sustainable Development and in the AU Agenda 2063 based on the recognition that these capabilities are prerequisites to enable technology serve as effective means of implementation.

If the STISA-2024 targets are met, Africa may be a step closer to building its own sound technological and dynamic industrial base it can leverage to meet its ambitious Agenda 2063 aspirations. For example, Africa desires to achieve 'middle income status with manufacturing accounting for 50% of the GDP and high-tech exports constituting at least 50% 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' (Agenda 2063). Such targets can only be met fully, equitably and sustainably if new and emerging technologies are fully embraced as they are transforming manufacturing and redefining high-tech exports.

New technologies open opportunities to create new industries, deliver new services, expand existing production systems, create incomes and reduce environmental degradation. For instance, steam and water powered systems ushered in mechanization (first industrial revolution); electricity enabled mass production in manufacturing (second industrial revolution) and; electronics and information technology brought about increased automation and digitalization of processes (third revolution). All these technological revolutions created new opportunities that have transformed the world. What will the world look like without electricity[3] or internet?

The Fourth Industrial Revolution is likely to be driven by increased convergence of digital, biological and physical systems. Advances in material sciences are enabling the development of smarter, stronger, smaller and energy efficient devices and systems while artificial intelligence is enabling remote service delivery, increased automation of homes, offices and factories and mass data analysis at incredible speeds. The highly anticipated COVID-19

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[1] Wu F, Zhao S, Yu B, Chen YM, Wang W, Song ZG, Hu Y, Tao ZW, Tian JH, Pei YY, Yuan ML, Zhang YL, Dai FH, Liu Y, Wang QM, Zheng JJ, Xu L, Holmes EC, Zhang YZ (2020). A new coronavirus associated with human respiratory disease in China. Nature. doi: 10.1038/s41586-020-2008-3.

[2] https://www.nature.com/immersive/d41586-020-03437-4/index.html

[3] Horvath, R. (1969) The Wandering Capitals of Ethiopia. *The Journal of African History*, 10 (2), 205-219. Retrieved February 2, 2021, from http://www.jstor.org/stable/179511

vaccines will not have been available without the use of incredible technological systems that integrate biological, digital and physical elements that enabled a quick decoding of the genetic makeup; identification of possible targets; rapid design of potential vaccines or simulations; analysis of the mountains of data from clinical trials and now helping in ensuring safe, fair and equitable access[4].

Emerging technologies promise to reduce the costs of undertaking research, offer endless opportunities for innovations and present opportunities to catch up with leading nations. Specifically, two of these emerging technologies – digital and nanotechnology- offer African countries different opportunities to produce and use knowledge, build more sustainable businesses and communities; diversify economic activities and accelerate regional integrations. In this regard, the report looks at the state of emerging technologies in Africa in recent times and the progress made. It then addresses the current growth trajectories from a scientific, technological as well as an economic perspective. It also discusses the potential benefits of these technologies for enhancing productivity and efficiency, human well-being and environmental benefits.

[4] https://blogs.worldbank.org/digital-development/digital-technologies-and-vaccine-deployment-opportunities-and-challenges

2. Emerging Technologies and Competitiveness

Technology is a major enabler of competitiveness in almost all sectors. Advances in technology often opens up new opportunities that drive innovation, emergence of new companies, improvement in the productivity and efficiency of existing ones. In recent times, the emergence of the Internet ushered in new businesses such as Google and Amazon and enhanced the productivity and efficiency of existing firms such as airlines, hotels, energy utilities and public institutions. In an open market, emerging technologies promote competitiveness and growth at the firm level by increasing speed (e.g. reducing the number of steps and time goods and services are produced and delivered), reducing costs (e.g. reduced energy consumption), improving quality (e.g. corrosion free metals), enhanced social and environmental impact (e.g. lower waste production), in meeting regulatory requirements (e.g. elimination of many chemicals that destroy the ozone layer in refrigeration systems), among others.

Emerging technologies tend to enhance many of the elements of competitiveness and in the process disrupt existing business models. The cases of improved hybrid seeds and fertilizers in increasing food production and averting hunger (e.g. the green revolution); the shipping container in transforming the shipping of goods around the world at lower costs and faster; the mobile money in transforming the financial sectors and the biotechnology in bringing in treatments in healthcare perhaps highlight the importance of emerging technologies in driving competitiveness.

While most of the improvements in competitiveness occur at firm-level (microeconomics), they explain most the variations in macroeconomic growth. The current trade dispute between the United States and China may be related to mastery of emerging technologies and the competitiveness they are conferring to firms and economic performance of the countries. The rapid growth of the Asian Tigers (and that of Japan) could be tied to their ability to participate in emerging technologies. It is nearly impossible to discuss the rise of Asian Tigers without the rise of microprocessors and the electronics whose technologies they acquired, mastered and became leading producers and innovators.

This requires countries to put in place appropriate policies and regulations that enable firms to acquire, master and develop new and emerging as well as existing technologies. Such policies may address support for research and development (R&D), human capital development, technology transfer, financial start-ups and build technology infrastructure. This is reaffirmed by the "Report of the Conference of Ministers on the work of its fifty-second session"[5] in which they called on ECA to "help member States to replicate good practices in digital economy" and on member States to "build their human and technological capacity" and "formulate integrated plans for the development of the digital and green economy".

3. Africa's place in the global market of emerging technologies

There is significant interest at the role of emerging technologies in driving Africa's transformation and in meeting the global Sustainable Development Goals (SDGs). This report looks at some of the opportunities and challenges that emerging technologies present and the technological, industrial and policy capabilities needed to harness and manage emerging technologies. It focuses on two broad categories of emerging technologies: a) digital

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

technologies and b) material sciences with a focus on nanotechnology that ECA continues to undertake policy research and advisory services to member States.

3.1 Trends in Artificial Intelligence

The digital economy is unpinned by several key technologies, some of which include artificial intelligent (AI), cloud computing, blockchain, Internet of Things (IoT), virtual reality, and augmented reality. However, as UNCTAD noted, China and United States currently own 75% of patents on blockchain, account for half of global spending on IoT and their firms accounts for three quarters of the global market of commercial cloud computing. As a result, China and the United States account for 90% of the 70 largest digital platform while Africa and Latin America account for a combined share of about one percent (1%). The battle for digital economy supremacy is perhaps fuelling the current trade tensions between the United States and China.

Artificial Intelligence (AI) is one of the digital technologies likely to have profound economic, social and environment contributions. The global market for AI is estimated to be growing at about 32%-42% per year – a very fast pace. While the actual value of the AI global market is small - worth about $27.2 billion in 2019, it is expected to hit between $267 billion and $312 billion by 2027[6][7]. Software, at 41%, accounts for a large share of the market for AI, followed by services and hardware. The rapid penetration of AI in every aspect of the society – from advertising to personal assistants on mobile phones and computers is driving demand and in return, investment in research and development for enhanced and novel services.

Like other technologies, it is the contribution of AI to business performance and economic growth that is driving greater investments by governments and companies alike. For instance, one estimate suggests that by 2030, AI will "contribute up to $15.7 trillion to the global economy"[8]. Of that, consumption of AI is estimated to account for $9.1 trillion and increased production is likely to account for the $6.6 trillion. If Africa can only grab a 10% of the global GDP contribution of AI, Africa could see its GDP add about $1.5 trillion by 2030 – about 50% of its current GDP – due to AI alone. As growth may imply creation of additional high value and decent jobs, reduction in poverty, increased productivity of firms, better living conditions and enhanced environmental wellbeing.

Africa has all the right ingredients to capture a large share of AI driven economy to advance its social and environmental wellbeing. It has a young, curious, tech savvy and entrepreneurial population that is increasingly educated. The high education sector is growing at a very fast pace, growing middle class and increased integration of the continental economy.

3.1.1. What is AI?

It is perhaps necessary to define what AI may be and what it may not be. An oversimplified description of AI is a collection of technologies that enable machines to learn, adapt and act almost with human-like intelligence at incredible speeds. **Approaches to AI include thinking and acting humanly and/or rationally. Thinking and acting humanly is the approach to AI that simulates human or biological systems, while thinking and acting rationally is being able to do the right thing given known knowledge or conditions.** It was on 11 May 1997 IBM's Deep Blue beat the Chess Grand Master - Garry Kasparov - and two decades later, computers developed by Google and HNH Entertainment Corp (Republic of Korea) had

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[6] https://www.fortunebusinessinsights.com/industry-reports/artificial-intelligence-market-100114
[7] https://www.grandviewresearch.com/industry-analysis/artificial-intelligence-ai-market#:~:text=The%20global%20artificial%20intelligence%20market,42.2%25%20from%202020%20to%202027.
[8] https://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf

defeated world champions at Go – a game more complex than chess – that highlighted the power of AI. In these cases, the computers are taught (or learn) the steps and rules of the game and then go ahead to create new ways of learning, making decisions and acting that they soon outsmart their human opponents that traditionally rely on intuition and experience.

AI may include systems that analyse massive amounts of data to make or inform decision making in areas such as advertising, health, agriculture, manufacturing, education, transportation, among others. As COVID-19 has demonstrated, while governments and institutions depend on sharing official data, an AI-based start-up whose system can understand 65 languages and has access to global air ticketing system predicted more accurately the COVID-19 spread from China[9]. By picking up on chatter, travel patterns and nature of infections reported, BlueDot[10] had predicted the spread of COVID-19 from China to cities in Asia and beyond, just like it did in the spread of zika virus from Brazil to United States.

AI differs widely from simple automation, which may be enabling machines to undertake repetitive human-like acts such as those in assembly lines of factories and in warehouses. In this case, machines are trained to perform a specific act perfectly and performs that act in the same way repetitively until perhaps programmed to perform another task. Usually, allowing a system to evolve on its own is limited to simulated environments where the outcomes can be observed in order to measure how to apply such a system in the real world given some evolvability constraints. This is important especially where the desire is to make perfect copies of the same product – a chip, lab test, car or drug. It may not be desirable to find machines on the factory floor have made changes that regulators did not approve in the design of a drug or medical device, for example. Simple automation is desired in such cases

AI is a range of areas such as Machine Learning, Natural Language Processing, Image Analysis and Computer Vision, Fuzzy Systems, Evolutionary Computation, and Probabilistic Methods. Several hospitals now employ some form of AI to analyse images and make predictions based on object recognition software, and many home assistants are taught to learn the house owner's voice signature so that it can only take commands from the right person to open the door, switch off lights etc. These are different areas of AI and are underpinned by various technologies. For a detailed overview of some of the common areas of AI, see Table 1.

Table 1: Examples on main AI areas and their description

AI Areas	Description
Large-scale Machine Learning	Large-scale Machine Learning Design of learning algorithms, as well as scaling existing algorithms, to work with extremely large data sets.
Deep Learning	Model composed of inputs such as image or audio and several hidden layers of sub-models that serve as input for the next layer and ultimately an output or activation function
Natural Language Processing	Algorithms that process human language input and convert it into understandable representations.
Collaborative Systems	Models and algorithms to help develop autonomous systems that can work collaboratively with other systems and with humans.
Computer Vision (Image Analytics)	The process of pulling relevant information from an image or sets of images for advanced classification and analysis.
Algorithmic Game Theory and	Systems that address the economic and social computing dimensions of AI, such as how systems can handle potentially misaligned incentives, including

[9] https://www.wired.com/story/ai-epidemiologist-wuhan-public-health-warnings/
[10] https://bluedot.global/

Computational Social Choice	self-interested human participants or firms and the automated AI-based agents representing them.
Soft Robotics (Robotic Process Automation)	Automation of repetitive tasks and common processes such as IT, customer servicing and sales without the need to transform existing IT system maps.
Evolutionary Computation	Systems that address the optimization problems such as detecting the best network to connect to or optimizing trade-offs between two or more factors, e.g The Travelling Salesman Problem. Evolutionary algorithms such as Genetic Algorithms, and Genetic Programming.
Neuroevolution	Systems that address sub-optimization to solve dynamic problems or address strategic planning such as in evolutionary robotics, using evolutionary computation techniques such as genetic algorithms to evolve structures of artificial neural networks.

Source: Rao, A.S. and Verweij, G. (2017) Sizing the prize: what's the real value of AI for your business and how can you capitalise?, PwC and updates by author (https://www.pwc.com/gx/en/issues/analytics/assets/pwc-ai-analysis-sizing-the-prize-report.pdf)

3.1.2 AI potential and challenges in Africa.

Research has shown that AI has the potential to solve some of the most pressing challenges facing Africa and drive sustainable development in agriculture, health, infrastructure, financial and public services[11]. These are also some of the areas where the needs are high. Applications of AI may include modelling, detecting and tracking changes in the environment that could aid decision making to make industries and businesses more efficient, productive and profitable; service delivery more effective and; knowledge more accessible.

It is important for government to support research and development, technology acquisition and infrastructure development fit for the digital economy is Africa has to realize the immense opportunities offered by AI. For instance, global investment in AI start-ups has grown from $1.3 billion in 2010, to $37.4 billion by 2019 (an average annual growth rate of about 48%); AI computing power has doubled every 3.4 months; 58%of large businesses adopted AI in some of their operations (up from 47% in 2018) and 21% of graduating PhDs specialized in AI/Machine Learning[12]. Africa needs to match and outperform the global averages if it can address some of the key challenges.

Among the key challenges that African countries need to address are:

a) build the work force that is read for AI by addressing the education and **quality of** research and development (R&D) systems to ensure they are fit for purpose, innovative and entrepreneurial in nature,

b) encourage the public and private sector to collaborate in design of AI solutions, preferably locally to ensure learning takes place and trust is built,

c) promote open data and open access data and open government data principles to encourage research and businesses to build smart systems,

d) increase funding and investment in high-speed internet and cloud computing infrastructure with the security, speed and processing powers that AI demands and,

e) development of national and regional strategies that ensure a good balance between ethical and safety concerns and the research and business development interests.

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University of Pretoria (2018) Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation, Access Partnership (

12 Stanford University (2019) AI Index Report 2019, Stanford Human Centred Artificial Intelligence (https://hai.stanford.edu/sites/default/files/ai_index_2019_report.pdf)

The main advantage is that Africa is not starting from a scratch but just from a low base. Almost all countries in Africa have a university or universities with computer science, mathematics and/or engineering departments that could easily include AI in their teaching and research programmes, businesses that are exploring AI applications (e.g. financial, insurance, travel and hospitality industries etc) and government units that are or could incorporate AI in their services (e.g. education, health, public utilities). In addition, countries such as Egypt, Ghana, Kenya, Senegal and South Africa have attracted some of the world's top digital firms to set up research units that develop AI products.

3.2 Trends and steps to harness nanomaterials and nanotechnology[13]

This overview offers a glimpse at what is included in nanotechnology, the current nanotechnology research and development (R&D) trends and market potential and indirectly assesses Africa's participation in nanotechnology industry. It also highlights the sustainable developments goals (SDGs) that nanotechnology is likely to have a greater impact and steps African countries can take to develop and realise the nanotechnology potential.

3.2.1 Concepts, definitions and markets

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 finished products that incorporate nanomaterial. It is nearly impossible to avoid products that includes 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.

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, super-conducting wires, fabrics	Electronic devices, medicine, plastics, cars

Source: Michael Berger (2017) Debunking the trillion dollar nanotechnology market size hype, Nanowerk. **(https://www.nanowerk.com/spotlight/spotid=1792.php)**

The 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

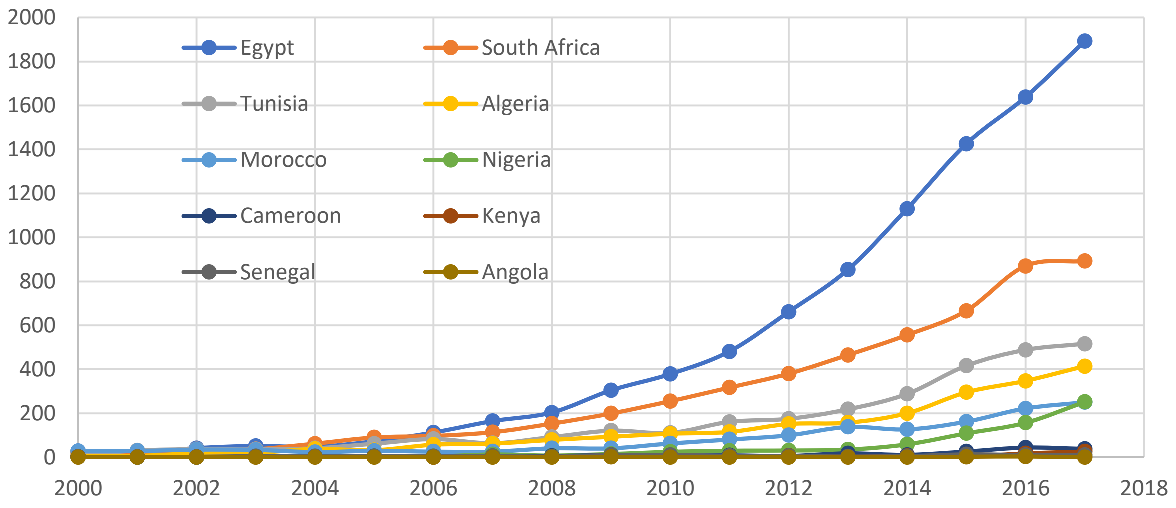
[13] This section is primarily based on the outcome of the Expert Group Meeting on 'An African Nanotechnology future? Policies and Regulations"

usually enables novel applications." Nanotechnology include nanomaterials, nanoelectronics, nanophotonics, nanomedicine, nanomagnetics, and nanomechanics.

In brief, nanotechnology refers to manipulation of matter at nano-scale (about a billionth of a meter) at which matter exhibits different chemical and physical properties from those at every day scale. For instance, silver oxide is white at normal scale but transparent at nanoscale and carbon will conduct electricity at nanoscale. It is these changes in the properties of matter at nanoscale that are behind the decreasing size of chips in mobile phones, computers and cars, improvements in drug targeting of cancer treatment with minimal side-effects, advance in cleaning materials and surfaces that repel dirt, packing material that kill bacteria, filters that clean air and water with minimal energy use, among others.

It is these developments that are driving growth in nanotechnology-enabled products. For instance, the National Research Foundation supported research by Lux Research Inc concluded that revenues from nanotechnology enabled-products increased from US$850 million in 2012 to about $1.6 trillion in 2014 – a growth of about 90%[14]. The strong growth in nanotechnology market is partly driven by increasing investment in R&D that is bringing new industrial applications at a very rapid pace. The number of nanotechnology related science publications have grown from about 13,000 in 1997 to 154,000 in 2016 – a 14% annual growth rate (Zhang, 2017)[15] and way higher than the estimated 3.7% annual growth rate in research papers across all fields of research during that same time. A number of developing countries (e.g. China, Iran, Saudi Arabia) are among the top R&D performing countries in nanotechnology. African countries such as Egypt, Tunisia and South Africa are making steady investment in nanotechnology.

Figure 1: Nanotechnology articles by the top 10 African countries



[14] Lux Research (2015) Nanotechnology Update: U.S. Leads in Government Spending Amidst Increased Spending Across Asia, Lux Research Inc.

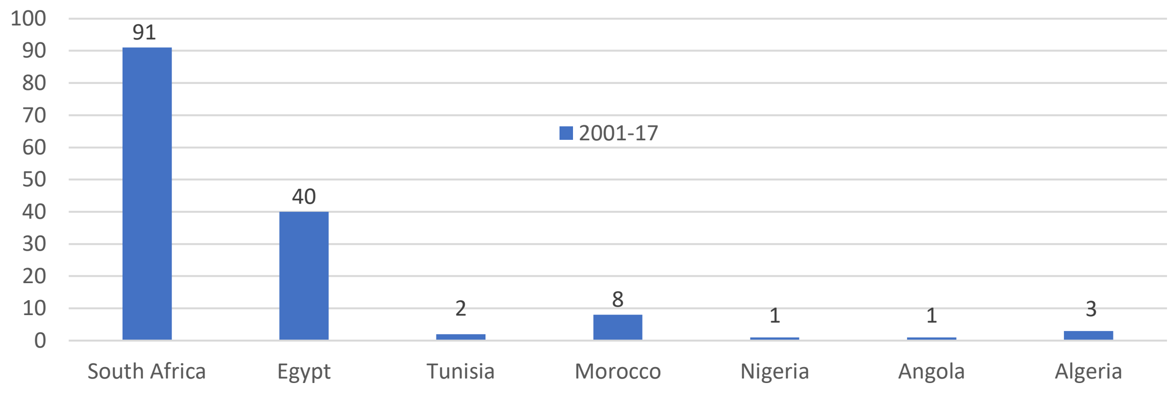
[15] Zhang Li (2017) Nanoscience as a microcosm of the success of Chinese science; Springer Nature,

Source: Statnano database

This is also reflected in the number of patents in the USPTO and EPO. Between 2001 and 2017, about 141,170 patent applications were filed with the two offices. The United States remains the largest contributor followed by Korea, Japan and Germany. Between 2010 and 2017, the fastest growth rate was posted by Saudi Arabia (about 2000% from 8 to 167 applications), followed by China (143%) and Korea (71%). However, most of the mature economies registered modest growth rates during this period.

At the continental level, South Africa has 87 patent applications for nanotechnology-related inventions filed in the USPTO and only seven in the EPO between 2001 and 2017. All of the 40 patent applications of Egypt were filed in the the USPTO. Although a growth in the number of patent applications is observed in the few African countries, it remains uneven and rather small. For instance, Saudi Arabia applied for more nanotechnology patents in 2017 in the USPTO than South Africa or Egypt did in the last 17 years (Figure 2). The continent seem to be lagging behind.

Figure 2: Patent applications by African countries (Sum of 2001-2017)



Source: Statnano database

3.2.2 Nanotechnology and the Sustainable Development Goals

Although nanotechnology will impact all aspects of life, its greater impact is likely to be on SDGs 2 (Food), SDG 3 (Health), SDG 7 (Energy), SDG 8 (Employment), SDG 9 (Infrastructures/innovation), SDG 11 (cities) and SDG 12 (Responsible Consumption) where most of the private investment in R&D is targeted. It is these areas where patents granted and high impact technologies by applications are concentrated. However, its impact on other SDGs will be equally important but likely to be indirect unless the continent invests in key nanotechnology applications with limited industrial interest (e.g. water, climate change and peace and security).

In general, emerging technologies present significant opportunities for the continent to catch up with leading countries before entry barriers become steep. For instance, several large businesses exploring markets are more likely to partner with African countries now than after the markets elsewhere have matured, standards have been established and intellectual assets are tightly controlled. This was clearly demonstrated by Internet and mobile phone revolutions. African start-ups got support from partners everywhere with limited restriction and grew rapidly. The success of these early entrants led to increased demand for higher standards, firmer regulations, and increased competition from larger foreign firms.

3.2.3 Key steps to harness nanotechnology for development

<u>*Capacity Building Initiatives in Nanotechnology is Emerging*</u>

A number of African countries have designed and others are in the process of designing and implementing national nanotechnology strategies and initiatives. Frontrunners such as South Africa can help drive nanotechnology capacity building for industrial (e.g. processing, bioprocessing, and manufacturing) and social (clean water, energy, and primary healthcare) sectors. *African countries should take steps to develop nanotechnology policies, strategies and policies, and use the budding nanotechnology research centres to build their nanotechnology capacity in selected areas with greater chances of success.*

<u>*Building Regional Research and Industrial Networks in Nanotechnology*</u>

In the context of the emerging Africa Continental Free Trade Area as well as in the rise of regional science, technology and innovations activities at RECs levels, regional blocks can serve as vehicles for developing common strategies, research infrastructure, innovation spaces and industrial nanotechnology platforms. Currently, African countries are largely collaborating more with partners outside the continent than their neighbours. *Measures to create a platform or inventory of nanotechnology research facilities and experts could enhance intra-regional collaboration; and efforts to promote intra-African collaboration in building nanotechnology research, innovation and entrepreneurship.*

<u>*Addressing social and regulatory challenges of nanotechnology in Africa*</u>

Nanotechnology poses many social and regulatory challenges for developed and developing countries alike. The absence of a globally agreed regulatory regime to manage the risks and uncertainties posed by nanotechnology at research and development (e.g. handling and manipulating nanomaterials); industrial applications (e.g. production, usage, labelling and intellectual property) and social issues (e.g. employment, security, environmental etc), among others, pose a challenge. *Africa could follow the examples of Korea and South Africa that initially focussed on building nanotechnology capabilities. In addition, African countries should participate fully in bodies that are developing and setting new regulations and standards for nanotechnology. These include take into consideration ethical engagement, socio-economic and environmental governance of nanotechnology.*

<u>*Leveraging of international cooperation and collaboration in nanotechnology*</u>

International collaboration is important in accessing global knowledge and other resources (e.g. advanced infrastructure, funding, markets, practices, networks etc), all of which can inform and drive nanotechnology development. African *countries need to identify areas of interest; should be willing to invest resources in international collaboration with clear targets and goals to be achieved; and identify and carefully select international partners that complement, advance and help build national efforts, preferably from a range of countries.*

<u>*3.2.4 Looking ahead*</u>

Nanotechnology remains a key component and a viable option of African's industrialization ambitions to achieve the 2030 Agenda for Sustainable Development and the African Union's Agenda 2063. Nanotechnology products are not only in African shops and homes but also nanotechnology research is starting to emerge in many African countries. With the rapid growth in and demand for infrastructure, Africa has the opportunity to use alternative low cost and environmentally friendly nanotechnology solutions to meet its water and sanitation, health, transport, energy and industrial and social needs. It is up to African countries, regions and continental bodies to determine their nanotechnology priorities, development the necessary strategies and policies needed to realise their goals. These could help identify potential regional and international strategic collaborators, shape cooperation agreements and guide national involvement, investment and participation in the global nanotechnology industry.

4. Regional perspective to harness emerging technologies

In the context of the 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.

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.

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.

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.

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.

Conclusion

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.

However, the full benefits of emerging technologies such as AI and nanotechnology will not accrue to Africa unless a number of simple steps are taken. These should include developing national and regional strategies in AI and nanotechnology that balance evenly economic, social and environmental aspects of technology; invest in building a workforce that is empowered to design, produce, operate and further upgrade emerging technologies; work closely with the private sector to build the adequate research and communication infrastructure that are secure and reliable and; put in place adequate data protection measures that enable access without sacrificing rights of consumers and security of countries.

The main advantage is that Africa is not starting from a scratch but just from a low base. Almost all countries in Africa have a university or universities with computer science, mathematics and/or engineering departments that could easily include AI in their teaching and research programmes, businesses that are exploring AI applications (e.g. financial, insurance, travel and hospitality industries etc) and government units that are or could incorporate AI in their services (e.g. education, health, public utilities). In addition, countries such as Egypt, Ghana, Kenya, Senegal and South Africa have attracted some of the world's top digital firms to set up research units that develop AI products. Steps are taken to African countries have to invest a

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?