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Adoption of Artificial Intelligence Technologies in African Firms for Potential Export-led Industrialisation

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Abstract

This report seeks to understand the role and potential of 4IR technologies, especially artificial intelligence (AI), for promoting export-led industrialisation. This document provides a brief scoping of African firms and industries that have adopted AI technologies for production, services and growth. First, the report explores AI developments across Africa by unpacking Africa's digital economy and its potential for AI adoption. The paper outlines countries that are leading the pack in AI-led initiatives and those that are lagging behind. Second, the report explores developments in AI adoption in various industries, in addition to government support mechanisms that exist to encourage AI research and development. The closing sections discuss the export potential presented by AI for manufacturing and international trade, with findings that digital technologies are unavoidable inputs into global value chains and that AI technologies will play a positive role in Africa's global value chain participation.

Introduction

The concept of artificial intelligence (AI) was initially introduced by American science fiction writer Isaac Asimov in the early 1940s, and found its roots in the "Three Laws of Robotics" (Haelein and Kaplan 2019). AI terminology was established in 1956 by scientists Marvin Minsky and John McCarthy at Dartmouth College (Butcher et al. 2021).

About the author

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This study is part of a broader project promoted by the DSI/NRF South African Research Chair in Industrial Development, University of Johannesburg examining the dynamics, requirements and implications of the adoption of 4IR technologies in African manufacturing. The current study received guidance and inputs from Dr Phumzile Ncube and Professor Fiona Tregenna.

Artificial intelligence has evolved over the years and has various definitions. Enholm et al. (2021, p. 1) define AI as a "wide-ranging set of technologies that promise several advantages for organizations in terms of added business value". Kok et al. (2019, p. 2) provide a number of definitions that view AI as an "area of study in the field of computer science, which is concerned with the development of computers able to engage in human-like thought processes such as learning, reasoning, and self-correction. The concept that machines can be improved to assume some capabilities normally thought to be like human intelligence such as learning, adapting, self-correction; the extension of human intelligence through the use of computers, as in times past physical power was extended through the use of mechanical tools and in a restricted sense, the study of techniques to use computers more effectively by improved programming techniques."

Artificial intelligence (AI) is the component of technology that enables machines to demonstrate human-like cognition, where the human-like capabilities are augmented by the ability to learn from experience and adapt over time (Access Partnership 2018). AI is expected to be used for industrial automation, disrupting modes of production and the delivery of services (Access Partnership 2018). Global investment in AI increased by between $20 billion and $30 billion in 2016 (Gadzala 2018) – more than three times the value in 2013 (McKinsey Global Institute 2017). Ten percent of this investment has been expended on AI acquisition and 90% on research, development and deployment, with the majority of investments made by Amazon, Baidu and Google. Venture capitalists ($4 to $5 billion) and private equity firms ($1 to $3 billion) have also found their footing (Gadzala 2018; Tralac 2019).

According to Ndung'u and Signé (2020), advanced economies spend an average of 3.2% of their GDP on digital investment, while Africa spends 1.1%. An OECD Report (2019, p. 4) says that "Global spending on AI is forecast to double over the next four years, growing from $50.1 billion in 2020 to more than $110 billion in 2024".

A report by PricewaterhouseCoopers (2017) estimates that, by 2030, the adoption of AI technologies could increase global GDP by $15.7 trillion (14%), with $1.2 trillion potentially being attributed to Africa, Oceania and other Asian markets (5.6% of GDP). The markets that are well positioned and expected to gain the most are those that are more digitally advanced, such as China (26% of GDP in 2030) and North America (14%) (Wairegi et al. 2021).

In Africa, the prospects of AI ride on the back of mobile technology (mobile phone usage/ ownership) and social media usage, which have improved significantly over the years (Africa Renewal, 2022). The most widespread cases of AI adoption in Africa are found in Ghana, Ethiopia, Kenya, Nigeria and South Africa (Gadzala 2018), with the rest of the continent still lagging behind (International Monetary Fund [IMF] 2020; Tralac 2019). AI initiatives in these countries are still small-scale, but offer a promising future. Most African countries need the necessary reforms in data collection and privacy, infrastructure, education and governance in order to exploit the economic benefits of AI technologies (World Wide Web Foundation 2017).

AI depends on a number of factors for its adoption to be meaningful. These factors include:

- the availability and accessibility of large data volumes (big data), and machines to decode, process, analyse and synthesise data for decision-making (Adeniran and Osakwe 2021; Marwala 2019);
- the existence of the human knowledge and skills required to implement AI-enabled operations (Marwala 2019);

- a consumer market that is ready for and comfortable with AI usage (Candelon et al. 2021); and
- Good governance (Adeniran and Osakwe 2021; Besaw and Filitz 2019).

The rest of this report is structured as follows. Section 2 discusses Africa's digital economy, the need for increased and reliable internet access and different African countries' digital readiness. Section 3 zooms in on African government support structures for AI and privately supported AI initiatives. Section 4 discusses AI within the context of manufacturing. Section 5 focuses on digitisation and trade and explores the benefits of AI for regional and international trade. Section 6 concludes. An appendix is available that provides information on non-manufacturing firms adopting AI in their operations.

Africa's Digital Economy

Internet infrastructure and Connectivity

Digital transformation has been on the agenda of many African governments, with the African Union (AU) and its development partners having developed a digital transformation strategy for the region (Akuetteh and Pisa, 2022). This strategy is projected to increase Africa's GDP by two percentage points per year. The strategy is a roadmap for promoting a fully integrated and inclusive society by 2030. Although different African countries have their own digital transformation journey and initiatives, internet access still remains a weakness in the light of further technology adoption. An average of 40% of Africa's population has access to internet, thus lagging behind the rest of the world with a global average of 63% (Adeniran and Osakwe 2021; Tralac 2019). The cost and quality of digital infrastructure and access to internet-enabled devices remain a major barrier to digital development and adoption. Slow 2G still accounts for 59% of the available mobile technology, with 4G penetration at 6% (Adeniran and Osakwe 2021); advanced economies are already in the 5G era.

A report by GSMA (2021) states that, by 2025, Sub-Saharan Africa will have 615 million mobile subscribers, who will constitute 50% of the region's population, while 28% of all connections will be on 4G, with 3% on 5G and mobile technologies (GSMA 2021).

African countries and regions are at different levels of digital maturity, readiness and governance. Drawing insights from a Tralac (2019) report, which measured market readiness as B2B ICT use, WEF networked readiness and firms' technology absorption, the regional market readiness levels are detailed in Table 1 below.

Table 1: *The top and bottom African countries' digital market readiness according to ICT usage, network readiness and firms' adoption of technology*

Top Countries: Common Market for Eastern and Southern Africa (COMESA)	**Bottom Countries:** Common Market for Eastern and Southern Africa (COMESA)	**Top Countries:** Economic Community of Western African States (ECOWAS)
•Kenya •Rwanda •Egypt •Zambia •Mauritius •Seychelles	•Burundi •Malawi •Swaziland •Zimbabwe	•Senegal •Cape Verde •Nigeria •Benin •Cote d'Ivoire •Ghana •Gambia
Highest on technology readiness: Eastern Africa	**Top Countries:** Community of Sahel-Saharan States	**Top Countries:** Southern African Development Community region (SADC)
•Kenya •Rwanda •Uganda •Tanzania	•Kenya •Egypt •Senegal •Nigeria •Benin	•South Africa •Namibia •Zambia •Mauritius •Botswana
Bottom Countries: SADC	Intergovernmental Authority on Development	Community of Central African States
•Lesotho •Malawi •Swaziland •Zimbabwe	•Kenya •Uganda •Ethiopia	•Cameroon •Gabon •Chad

Source: Tralac 2019

Approximately 22 African countries (out of a possible 54) are market-ready. These, in no particular order, are: Kenya, Rwanda, Egypt, Zambia, Mauritius, Senegal, Cape Verde, Benin, Côte d'Ivoire, Ghana, The Gambia, Uganda, Tanzania, Nigeria, South Africa, Namibia, Zambia, Botswana, Ethiopia, Cameroon, Gabon and Chad. This means these countries have the basic technological infrastructure on which improved technology initiatives and technologies can be introduced.

Country Rankings in Artificial Intelligence

The economies that provide low-hanging fruit for AI, according to the Government AI Readiness Index (Oxford Insights 2020), are the following top five African countries: Mauritius (45th), South Africa (59th), Seychelles (68th), Kenya (71st) and Rwanda (87th). The index measurements are based on government, technology, data and infrastructure; and investments in vehicles, ports, roads and physical infrastructure, which are critical for the efficient provision of the mobility services required by AI (Nayebare 2019). Stanford's Global AI Vibrancy Tool, which provides a cross- and intra-country detailed comparison, has only one African country on its list – South Africa (Gwagwa et al. 2021), with Nigeria (42nd) and South Africa (38th) ranking the highest for innovation and uptake for AI.

African Support for Artificial Intelligence Initiatives

The cost to digitally transform Africa is estimated at between $80 and $100 billon over 10 years (Ndung'u and Signé 2018). Despite the many digital- and AI-adoption challenges confronting Africa, some level of AI-related solutions are already being deployed in Ghana, Ethiopia, Kenya, Nigeria and South Africa in the health, agriculture and financial services sectors (Ndung'u and Signé 2018; World Wide Web Foundation 2017). AI ecosystems also exist in these countries, with the main investors being multinational corporations, such as Amazon, Google, Facebook, IBM, Intel, Microsoft and Salesforce (Gadzala 2018).

Examples of these can be found in the appendix section.

Government Support for Artificial Intelligence

Numerous African governments have made technology such as AI a national priority. The Kenyan Ministry of Information, Communication and Technology (ICT) has formed a "Blockchain and Artificial Intelligence Taskforce" to understand how these technologies can be optimally used for the country's economic advancement (Gadzala 2018; Mpala 2019). The team was expected to develop a 15-year roadmap with key milestones, with one published in 2019 and another for 2037. Kenya is one of the highest market-ready countries and ranks within the top 100 in the Global Government AI Readiness Index (Gwagwa et al. 2021.)

The Nigerian government (high in ICT and AI readiness rankings) approved the establishment of a robotics and AI agency, located in its energy-endowed southeast region, while tech hubs have been mushrooming outside its capital city, Lagos, particularly in Enugu, Abuja, Ibadan and Port Harcourt (Gadzala 2018). Nigeria has also established a National Agency for Research in Robotics and Artificial Intelligence (NARRI), which provides AI skills training (Nayebare 2019). This will assist in hastening the skills required to capture AI-related economic growth.

Ethiopia has an "Artificial Intelligence and Robotics Center of Excellence" at its Addis Ababa Science and Technology University, where AI-powered solutions for the country's agriculture sector are being developed, e.g. flying insects to support the crop surveillance process. Though not AI-specific, the Mauritian government launched an extensive policy framework in 2018, named "Digital Mauritius 2030". The main objective of this is to drive and support economic development through ICT governance and talent management initiatives incorporated in broadband, intellectual property rights, data and cyber-security protection (UNIDO 2019).

Artificial Intelligence Tech-hubs and Initiatives

Africa is seeing a growing number of tech-hubs and AI-driven initiatives, with a large number of them concentrated in four countries. Of these countries, South Africa and Nigeria have the highest number of tech hubs, at 59 and 55 hubs respectively. Kenya has 30 hubs, while Ghana has 24 (Gadzala 2018; Gwagwa et al. 2021). Most of these hubs work in collaboration with academic institutions, both locally and internationally (Gadzala 2018). In Kenya, IBM has spearheaded a research laboratory for technological development, while Google and Microsoft have established AI hubs in Ghana and Kenya (Gwagwa et al. 2021). Kenya has also launched data centres, with the objective to make government data publicly accessible for accountability purposes.

IBM runs AI-driven facilities in South Africa and Kenya and launched its messaging app, Watson Workspace, in these countries. In Nigeria (Lagos), Facebook has established its first African technology hub, which offers AI training programmes. iCogLabs, which is based in Addis Ababa in Ethiopia, is a privately owned AI research lab that supports its Ethiopian and global clients with a range of AI research and development services. These align with the government's goal to prioritise development in the education and agriculture sectors (Ndung'u and Signé 2019).

IBM Research Africa utilises AI to gain an understanding of the most effective and efficient methods to eliminate malaria (Ndung'u and Signé 2019). Being the most advanced in AI resources, South Africa has a robust AI ecosystem boasting technology hubs, research groups, and forums (the AI Summit), with the Africa Automation and Technology Fair to be hosted in the country in 2023. The Trade Fair's objective is to exchange industry experience in order to increase Africa's investment prospects in the manufacturing

sector. Other international organisations that have made investments in AI projects are Omdena, Bolesian and Element AI (Gwagwa et al. 2021).

In South Africa there are a few tech hubs that work in collaboration with academic institutions. LaunchLab, located at Stellenbosch University, incubates student-owned start-ups specialising in blockchain, fintech, 3D printing and AI (Gwagwa et al. 2021). South Africa also hosts the Centre for Artificial Intelligence Research (CAIR), a collaboration between the University of KwaZulu-Natal's School of Mathematics, Statistics and Computer Science and the Council for Science and Industrial Research. Finally, the country also hosts the University of Pretoria's (UP) Computational Intelligence Research Group and the University of Cape Town's (UCT) Robotics and Agents Lab and Mobile Intelligence Autonomous Systems, which develops autonomous and navigation systems.

These developments in the AI field through government, academic and multinational collaborations reflect an Africa that is preparing for an AI future in order to reap the potential benefits presented by the technology presents cross industries.

AI and Manufacturing

Africa's Manufacturing Industry Performance

Africa is considered to be the "next great manufacturing center" (Yuan Sun, 2017), with manufacturing accounting for a third of African countries' GDP. According to Tralac (2019), manufacturing output in Sub-Saharan Africa grew from $184 billion to $222 billion from 2018 to 2021, with an average annual growth rate of 9.2%, although it declined by 3.58% in 2020. Countries such as Uganda, Tanzania and Zambia grew above 5% annually during that period. Sub-Saharan African markets almost tripled their manufacturing exports to more than $140 billion between 2005 and 2015 (Tralac 2019). This growth has been accompanied by an increase in manufacturing foreign direct investment (FDI), as is evident in manufacturing investments accounting for a quarter of all Mozambique and Tanzania's FDI and approximately 40% in Rwanda (Tralac 2019).

The top African manufacturing export subsectors (by average annual growth rate from 2005 to 2016) are: plastics in non-primary form, medicinal and pharmaceutical products (manufacturing predominantly in South Africa, Kenya, Morocco and Egypt), automobiles, specialised machinery, essential oils for perfume materials, and cleaning, office machine and automatic data-processing machines, paper and paper manufactures, other transport equipment, manufacture of metal, and dyeing, tanning and colouring materials (Tralac 2019).

A McKinsey Global Institute (2016) report predicts that Africa has the potential to double its manufacturing output, from $500 billion to $930 billion by 2025. The report asserts that the majority of this output (three quarters) will be derived from local firms meeting domestic demand, because Africa imports one third of basic consumer products (food, beverages and processed goods). Re-localisation efforts are expected to boost domestic production, with the remaining one quarter being output that meets export demand (McKinsey Global Institute 2016). This will be achieved on the basis of African manufacturers' ability to meet domestic demand from both consumers and business, and the willingness of governments and firms to work together to establish solutions to the factors that hinder manufacturers' ability to meet both domestic and export demand.

Production Technologies and Artificial Intelligence

In their paper, authors Bettiol et al. (2020) explore how information and communication technologies (ICT) affect the roots of the fourth

industrial revolution (4IR). Their research identifies manufacturing ICT (Bettiol et al. 2020) as one of the three groups that affect industry adoption of the 4IR, with the ICT-related digital manufacturing technologies that are most likely to be adopted by manufacturing firms being 3D printing, robotics, big data and artificial intelligence.

Advanced digital production technologies (ADP) such as AI have started to radically disrupt manufacturing production. With approximately 70% of the manufacturing sector in "lagging economies" still using analogue technologies in their production, AI has the potential to foster inclusive and sustainable industrial development under well-structured conditions, as well as to accelerate innovation and increase the value-added content of manufacturing industry production (UNIDO 2019).

With the rise of ADP, firms in Africa are most likely to transition from analogue technologies to digital technologies to manage inventory and processes as they face increasing competition (UNIDO 2020; World Bank 2016). Digital technology fuels economic growth – although unevenly across economies – through inclusion, efficiency and innovation, leading to quality and service improvements, increases in demand, product diversification and new customers in new markets, thus presenting opportunities for restructuring the sector across value chains, particular for middle-income countries (Andreolli, Mondliwa, Roberts and Tregenna 2021; World Bank 2016).

Smart Manufacturing

The concept of smart manufacturing has been gaining momentum over recent years, with Gumbi and Twinomurinzi (2020) citing the benefits of its adoption as a key driver of improved manufacturing operations, as it enables the sector to become more efficient along its value and supply chains. Technological innovations for smart manufacturing can be applied through the adoption of flexible manufacturing systems (FMS), which serve to enhance monitoring and auto-correction, thus reducing costly delays, faulty products or incorrect product specifications, as well as problems in relation to quality, productivity and profits (Fofana, Nyarko and Takyi 2021). FMS is defined as "an integrated, computer-controlled complex structure of automated material-handling systems and numerically controlled (NC) machine tools that can process moderate volumes of a variety of part types at the same time" (Fofana et al. 2021). This, however, requires large amounts of data for intelligent manufacturing. Although common in other parts of the world, for example in Germany's construction sector, smart manufacturing is still nascent in Africa's ecosystem. However, Gumbi and Twinomurinzi (2020) contend that it is a catalyst for manufacturing intelligence.

An example of FMS usage is the computer numerical control (CNC) machine, which is a workstation that executes "machining operations on families of parts in modern applications" (Fofana et al. 2021). CNCs were widely used in companies in the 1980s and are becoming an integral component of the technological equipment developed for manufacturing companies, although their origination dates back to the 1950s, while laser cutting devices used for the customisation of fabric designs date back to the 1980s (Bettiol et al. 2020).

FMS is adopted predominantly in the aerospace, construction, military, mining and medical industries; however, global manufacturing firms that are reaping the benefits of FMS are Siemens, Mazda, Prince Industries, Toyota Motor Corporation, AREOTEC and Ford (Fofana et al, 2021). Examples of these are also seen in the furniture manufacturing industry, for example. In recently conducted fieldwork funded by the South African Research Chair in Industrial Development (SARChI-ID), an executive at Coricraft, one of the largest furniture manufacturers in South Africa, stated that they

had recently started manufacturing products using computer-aided design (CAD) and CNC technology. Coricraft mainly serves the domestic market (95%), while exporting the rest of its products to Europe (UK), Zimbabwe, Lesotho and Angola (regionally), with the firm looking to increase its technology adoption and grow its export share. Manufacturing ICT contains two technologies (CAD/CAM (computer-aided manufacturing) and CNC), which are found to be that the most commonly used in Italian manufacturing firms (Bettiol et al. 2020). The benefits include efficient, flexible production and customisation (Bettiol et al. 2020).

South African firm Bridgestone, a tyre manufacturer, and South African Pulp and Paper Industries (Sappi), a company that produces and sells commodity paper products, pulp, dissolving pulp, and forest and timber products to Southern Africa and export markets, are also examples of African firms investing in the digital AI cloud and production technologies (Gwagwa et al. 2021). In 2019, Bridgestone introduced Enliten, a new, lightweight tyre technology that requires less materials and cuts CO_2 emissions (Bridgestone 2020), while Sappi recently spent $480 million on a tech revamp to transition it into a smart factory (CNN 2022).

According to a CNN report (2022), the integration of AI, digitisation, robotics and big data (smart technology) has improved productivity by 12%, equipment availability by 25% and overall equipment efficiency by 35%, and this process was accelerated by Covid-19. CNN's data came from ABB, a multinational automation company providing services to Sappi.

Aligned with Enhom et al.'s (2021) definition of AI, the adoption of AI technologies has not only complemented manufacturing, but offers compounded benefits. For example, Sappi has reduced its water usage by 40% and its carbon footprint by 17%, while the company has increased its production by 110 000 tonnes to 900 000 tonnes (CNN 2022).

Considerations of trade in AI

Digitalisation and Trade

In relation to trade, digitalisation reduces costs by ensuring trade and business processes are optimised (IMF 2020). Search, language barriers and logistics coordination requirements are some of the costs that are minimised by diverting away from traditional to more modern delivery channels. According to Meltzer (2018), the adoption of digital solutions for trade will improve the effectiveness and efficiency of African exporters in the following ways:

- Reduce additional export charges (demurrage chargers for suppliers) through digitalised customs management and procedures, which can serve to improve regulatory inefficiencies, thus speeding up transit and export clearance
- Improve information flow for more valuable global supply chain participation
- Connect enterprises across jurisdictions and assist in the sharing of pertinent information (regulations and standards) amongst industry stakeholders
- Increase trade openness, as firms will have better knowledge of foreign market demands
- Improve the quantity and quality of data African firms can use, as the information flow will improve their feasibility and opportunities to participate in the high-value end of global value chains.

Digital technologies are unavoidable inputs into global value chains, therefore increased digital penetration (Africa Renewal 2020), coupled with sound digital policies and transparent data governance structures and

frameworks (Adeniran and Osakwe 2021), is crucial to achieve the industrial gains that come from AI adoption.

Regional and International Trade

Wamkele Mene, the Secretary General of the African Continental Free Trade Area (AfCFTA), noted that Africa exports more than 53% of its production to European markets and AfCFTA, and imports close to 60% (Cilliers 2018), which reveals the potential for domestic manufacturing. AfCFTA is seeking to increase intra-African trade from 18% to 50% by 2030 (Africa Renewal 2020), which means that intra-regional trade is a key and strategic focus of the continent's growth and industrialisation. However, this will require digital connectivity, with supporting policies that streamline regional integration in Africa by ensuring the free flow of data and information across countries, facilitate knowledge sharing and collaboration, reduce trade costs, and address the perpetual struggles of barriers to intra-regional trade (Adeniran and Osakwe 2021; Chivunga and Tempest 2021; Nayebare 2019). Therefore, the adequate and robust development of Africa's digital economy is an imperative launch pad for AI-led industrialisation and crucial for the continent's economic integration.

Digital trade is currently feasible through mobile phones (Africa Renewal 2020), and firms in African countries have been able to access distant markets using mobile technology. This can be leveraged robustly for further technological advancements like AI. It is anticipated that AI will increase productivity, which subsequently will lead to economic growth, thus offering new and additional opportunities for international trade (Meltzer 2018). Although it does take time to integrate complex technologies like AI into global value chains, the potential benefits are significant (Cilliers 2018). According to a UNIDO (2020) report, manufacturing firms adopting production technologies like AI have higher productivity, are more competitive and efficient, and increase their participation in global value chains (GVCs), although the authors do caution against full GVC digitalisation for developing countries due to the already high barriers to entry and fears around delocalisation, supply chain reorganising and possible manufacturing re-shoring.

AI improves predictions for future trends, effectively manages supply chain risks, manages complex and varied production units, improves warehouse management and demand predictions, and helps with the laborious inspection and maintenance of assets along the supply chain (Meltzer 2018). AI developments will not only strengthen and expand Africa's participation in GVCs, but international trade negotiations will also be affected (Chivunga and Tempest 2021; IMF 2020). Meltzer (2018) informs us that AI adoption can provide better analysis of the economic trajectories of individual negotiating countries with dissimilar assumptions. It could also clarify growth paths from various forms of trade liberalisation, and how these outcomes are affected in a multiplayer scenario where trade barriers are adjusted down at different rates. AI also has the ability to forecast the trade responses of countries not included in trade negotiations. Such reforms already exist in Brazil, where an Intelligence Tech and Trade Initiative has been established to improve trade negotiations using AI.

Conclusion

Most African countries are not AI ready; however, despite regional bottlenecks, there are business success stories in non-manufacturing sectors that signal a positive future for AI-led industrialisation that would increase the demand for African exports. Other industries, like Fintech, have paved the way by offering solutions that facilitate international trade in different ways, e.g. increased access to finance for firms, cross-border payment mechanisms, trade finance solutions, and

cheaper and more efficient ways to access data. These early-adopter industries form part of the industrialisation ecosystem, without which exports would not smoothly reach foreign destinations at the required standards and quality. The manufacturing industry seems to be a late adopter of AI technologies, with meagre evidence found through secondary information; the reality could be found to be different if primary information is obtained through assessments (fieldwork). When AI adoption does takes off, it will be supported by developing infrastructure from other sectors and manufacturing related to international trade services.

AI has the potential to improve Africa's manufacturing sector by accelerating the diversification of African economies, addressing Africa's resource curse and establishing a sustainable AI ecosystem that can weather economic and climate risks. Diversification is possible by intensifying capabilities for high growth–high value subsectors such as textiles, aerospace, military, medical, and automotive and driving. AI-led export growth in countries such as Egypt, Kenya, Morocco, South Africa, Tanzania and Tunisia, which have pro-manufacturing policies, acts as an incentive that attracts investment, enabling environments for pilots and AI-oriented manufacturing processes.

For AI to yield its fruits, supporting structures need to be developed, enhanced and implemented. These include connectivity, access to stable internet, and infrastructure to enable AI-led export production. African governments needs to play an active role in promoting AI research and industrial usage, and AI knowledge-sharing platforms are required to provide space for technologies. Local AI talent needs to be developed and retained, AI governance needs to be established with defined codes of conduct, public data needs to be available, data centres need to be built, and female representation is needed to boost industry growth and development.

To ensure that AI solutions are locally viable to generate economic benefit, a concerted effort is required between governments, manufacturers, tech hubs, research bodies and academic institutions. Connections between these stakeholders will promote AI innovation and facilitate teaching, research, product development and commercialisation. AI developments can therefore not be achieved in isolation, as this would disconnect the process from critical industry stakeholders and dampen AI-specific solutions for full industry value chains. The development of AI initiatives and hubs across Africa presents a positive and sustainable opportunity for the local establishment of research units like the Data and AI for African Trade (DAIAT) Consortium.

Appendix

Scoping and identifying case studies: African firms adopting AI across industries; Examples of AI developments across industries

1. Health and Pharmaceutical Production

South Africa: *NumberBoost* is for citizens in regions without primary healthcare facilities, the company is developing a system to allow people to locate nearby mobile healthcare clinics. *MomConnect* is a chatbot initiative of the National Department of Health that aims to support maternal health through the use of cell phone-based technologies integrated into maternal and child health services. Approximately 1.8 million pregnant women are connected to it and receive pre- and postnatal services. *Kiara* is an African pharmaceutical manufacturing and healthcare solutions company headquartered in Johannesburg that serves as the local, non-exclusive manufacturing partner for a global, top 5 pharmaceutical company and as a commercial partner for several global pharmaceutical and medical technology companies.

Kenya: *Sophie Bot* is a free chatbot that works on several popular messaging apps. It relies on AI to process and replies to questions on sexual and reproductive health.

Uganda: *mTRac* is used by 27 000 public health workers to improve medical data and service delivery and report on medicine stock. Through a private-public partnership, the *SMS for Life Program* serves to reduce shortages of medicine by applying mobile phone technology to track and manage malaria stock levels and other essential medication.

Rwanda: The first African country to integrate drones into its healthcare services, where autonomous vehicles are used to deliver blood transfusions to remote areas.

West Africa: *WhatsApp* was used to disseminate information about the 2014 Ebola outbreak, check symptoms and keep quarantined individuals informed.

Ethiopia: Gradual AI adoption has played an assisting role in the correct diagnosis of cervical cancer.

Nigeria: *Ubenwa* uses inbuilt smartphone microphones and speech recognition algorithms to detect birth asphyxia (a condition that occurs when a baby's brain and other organs do not get enough oxygen and nutrients before, during or right after birth). The condition is identified based on the amplitude and frequency of a new-born baby's cry.

2. Agriculture and Agro-processing

South Africa: *Aerobotics* assists the agricultural industry by using aerial drone imagery to identify problems in crop yields, which is particularly necessary during drought seasons.

Nigeria: *Zenvus* seeks to improve decision-making for farmers by providing insights based on data collected from sensors.

Kenya: *Vital* analyses pixel value and colour from satellite imagery data to estimate rainfall and drought patterns. *Arifu* provides curated access to information via SMS to help farmers determine what fertiliser matches their specific needs. *FarmDrive* offers credit for farmers in need of supplies (e.g. fertiliser) by relying on data such as the size of land, location and crops to determine the risk and corresponding interest rates. *UjuziKilimo* is a farming app that relies on existing SMS technology to assist Kenyan farmers to optimise their irrigation practices through machine learning and data analytics.

Kenya's floriculture industry comprises large-, medium- and small-scale producers who have developed to attain high management standards and have invested heavily in the adoption of modern technology in production, precision farming and marketing. The farmers utilise technologies that include drip irrigation, fertigation (the injection of fertilisers) systems, greenhouse ventilation systems, net shading, pre-cooling, cold storage facilities, grading, bouqueting, fertiliser recycling systems to prevent wastage, wetlands for wastewater treatment, artificial lighting to increase day length, grading/packaging sheds, and refrigerated trucks. According to Africa Business pages, an e-commerce platform that connects Europe to African markets, Kenya has a 40% market share as an exporter of cut roses to the European Union (EU).

Ghana: *Farmline* and *Agrocenta* provide farmers with agricultural advice, weather information and financial tips through their mobile and web technology.

Uganda: *Sparky Dryer* is a dehydration machine that uses biofuel to reduce waste and dehydrate produce.

3. Financial Services

Kenya: *Tala* uses a mobile app to assess and disburse loans to customers who do not have a credit history. Through the app, the company can assess these traditionally excluded customers by analysing Facebook and SMS data to determine a customer's risk of default. *Mpesa's* mobile money transfer platform has

the highest number of mobile money transfers in the world, which enables other AI technologies to leverage the application and integrate their service offering with less stringent limitations.

Nigeria: *Kudi.ai* has developed a system that allows users to improve money transfers. Using natural language processing and artificial intelligence, *Kudi.ai* attempts to make peer-to-peer payment easier for Nigerians using a chatbot that works on popular messaging apps, like Facebook Messenger. *Carbon*, a mobile lending platform, uses machine learning to evaluate credit applications.

South Africa: *Nzone* is the digital branch of Nedbank; the branch uses virtual reality to interact with clients and prospective customers while eliminating the need for tellers. Nzone uses facial recognition as a client enters the branch. The digital bank provides intelligent depositing, video and quick chat banking, a grab-and-learn wall and an interactive demo station.

4. Public Transport

Nigeria: *RoadPreppers* provides a solution that allows users to navigate traffic congestion, with driving directions and public transport options. In addition, the app *lara.ng* uses a chatbot to provide public transportation directions and fares for commuters in Lagos. Both are viewed as better options when compared to Google Maps because they provide the commuter with more transparent information on the fares of different public transport providers.

South Africa: *Gautrain* uses Opgal's thermal cameras, combined with ioimage intelligent video analytics, to monitor the tracks and tunnels of the Gautrain rail. These technologies were chosen because of their high probability of detection and low false alarm rate.

Kenya: *Little* is a ride-hailing app that uses AI to assess driver performance.

5. Education

Kenya: *M-shule* and **Nigeria:** *Tuteria* use AI technology to provide extensive and accessible training and learning platforms to analyse students' performance, and provide personalised learning material and tutoring services.

6. Entertainment

South Africa: *MultiChoice* has an artificial intelligence (AI) chatbot (AI-powered assistant) called The Ultimate Master of Information, or TUMI, embedded with natural language capabilities. This innovative service is available 24/7 to answer customer queries about products and services.

7. Natural Language Processing

South Africa: The *Council for Scientific and Industrial Research (CSIR)* works on the use of automatic speech recognition to support language learning and translation. This is an important and complex task, given that there are eleven official languages in the country, with most existing language technology options limited to English and Afrikaans.

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