GROWTH THROUGH INNOVATION:

Harnessing data and frontier technologies for Africa's economic transformation

ECONOMIC REPORT ON AFRICA

United Nations
Economic Commission for Africa

2026

GROWTH THROUGH INNOVATION:

Harnessing data and frontier technologies for Africa's economic transformation

ECONOMIC REPORT ON AFRICA

United Nations
Economic Commission for Africa

2026

Economic Commission for Africa
P.O. Box 3001
Addis Ababa, Ethiopia
Tel: +251 11 544-9900
Fax: +251 11 551-4416
E-mail: eca-info@un.org
Web: www.uneca.org

Sales no: E.26.II.K.2
PRINT ISBN: 9789211548662
PDF ISBN: 9789211594157
Print ISSN: 2411-8346
Online ISSN: 2411-8354

Editing: Communications Development Incorporated, www.cdinet.com
Design: Dilucidar, www.dilucidar.com

Printed in Addis Ababa, Ethiopia by the ECA Printing and Publishing Unit. ISO 14001:2015 certified.

CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF BOXES

FOREWORD

Africa's development journey is entering a new phase. For decades, countries in the global economy competed largely on capital, labour, and natural resources. Today, competitiveness increasingly depends on a country's capacity to generate, govern, and apply data and frontier technologies. This shift is not only technological; it is economic and developmental.

A new economic system is emerging, powered by digital platforms, artificial intelligence, next-generation production technologies, biotechnology, and clean-energy innovation. These technologies are reshaping production, trade, and productivity and redefining labour markets. Beyond efficiency gains, frontier technologies can become engines of sustainable economic growth by enabling higher productivity, reducing production costs, improving resource efficiency and supporting low-carbon industrialization.

Significantly, these technologies function because they are powered by data. Artificial intelligence, digital platforms and next-generation production systems depend on the ability to collect, process, and use vast quantities of information. Data has therefore become a new factor of production, comparable to land, labour and capital in previous economic eras. When governed effectively, data can support better public policy, improve service delivery, strengthen markets, and enable more inclusive and resilient economic growth.

Against this backdrop, this edition of the ***Economic Report on Africa*** examines how data and frontier technologies will shape Africa's industrialization, competitiveness, and participation in global value chains.

Historically, the continent has participated in the global economy largely as a supplier of primary commodities. In a data-driven economy, however, value creation depends less on raw material extraction and more on knowledge, processing capability and technological capacity. Applying frontier technologies to production allows countries to move up value chains, diversify exports, and reduce vulnerability to commodity price cycles—all central to achieving sustained and inclusive growth. Without deliberate policy action, Africa risks remaining a consumer rather than a producer of digital value.

Much of the data generated in Africa is stored, processed, and monetized outside the continent. Indeed, Africa hosts less than 1 per cent of global data centres. When data are processed abroad, costs rise, delays increase, and sensitive information—including medical, financial, and security data—becomes more vulnerable. The implications go far beyond technology. This is an economic and sovereignty challenge. In the digital economy, those who control data infrastructure increasingly shape industrial development and participation in global value chains.

Yet Africa is not starting from a position of weakness. The continent possesses significant strategic advantages. Africa holds about 30 per cent of the world's critical minerals essential for clean-energy technologies. But the central question is whether Africa will export raw materials, or apply frontier technologies to build industries that transform them into batteries, processors, digital infrastructure, and advanced manufactured goods—thereby creating higher-value jobs and long-term growth.

Beyond manufacturing, frontier technologies also offer major opportunities in agriculture by improving productivity, optimizing resource use, and strengthening climate resilience. In this way, technological adoption can support food security, stabilize rural incomes, and promote environmentally sustainable growth across the continent. As production systems evolve, so too will the nature of work. Africa's demographic growth will become a dividend only if young people acquire digital, technical, and analytical skills; otherwise, technological change risks widening inequality rather than reducing it.

No country can navigate this transition alone. Regional integration will be decisive. The African Continental Free Trade Area can support industrialization, innovation, and investment. In this respect, frontier technologies can reduce transaction costs, improve transparency, and enhance trade efficiency, enabling Africa to leapfrog legacy systems. Greater trade efficiency expands markets for African firms, encourages investment, and supports sustained economic expansion.

No country can navigate this transition alone. Regional integration will be decisive. The African Continental Free Trade Area can support industrialization, innovation, and investment.

For this potential to materialize, strong national leadership, skills development, adoption by micro, small and medium enterprises, reliable infrastructure, and data governance frameworks are essential. Strategic investments in data infrastructure and energy generation can reinforce each other by enabling digital industries while supporting electricity demand and reliability. Such investments also facilitate the growth of clean industries and services, supporting a transition toward greener and more resilient economic structures.

Ultimately, none of this will be possible without financing. Public budgets alone will not suffice. Africa must strengthen domestic resource mobilization and mobilize long-term capital through its markets, pension funds, sovereign wealth funds, and blended finance instruments.

Accordingly, ERA 2026 identifies four priority policy directions: building sovereign digital and data infrastructure; investing in skills and innovation ecosystems; deepening regional markets through the AfCFTA; and mobilizing long-term financing for technological transformation.

I extend my sincere appreciation to the experts, policymakers, and stakeholders who contributed to this publication.

The moment before us is historic. The choices made in this decade will determine whether Africa participates in the next phase of globalization as a producer of technology-enabled value or remains primarily a market for it. The opportunity is real, but it will not materialize on its own. It requires deliberate policy, sustained investment, and coordinated regional action.

If pursued with urgency and collective leadership, Africa can transform data, innovation, and regional integration into the foundations of productive employment, industrialization, and shared prosperity. In doing so, frontier technologies can underpin a model of economic growth that is not only faster, but also more inclusive, environmentally sustainable, and resilient to external shocks.

Claver Gatete
Under-Secretary-General and Executive Secretary
United Nations Economic Commission for Africa

ABBREVIATIONS

ADCA	Africa Data Centres Association
ADEREE	National Agency for the Development of Renewable Energy and Energy Efficiency
AEUA	Alliance for Entrepreneurial Universities in Africa
AfCFTA	African Continental Free Trade Agreement
AfDB	African Development Bank
AGMS	Africa`s Green Minerals Strategy
AGRA	Green Revolution in Africa
AI	Artificial intelligence
AMAN	Appui à la Modernisation de l'Administration en Mauritanie (Support for the Modernization of Administration in Mauritania)
ASF	Algerian Startup Fund
ASM	Artisanal and Small-scale Mining
ATG	Africa Trade Gateway
AU	African Union
AUDA	African Union Development Agency
AWS	Amazon Web Services
BME	Biomedical engineering
BMW	Bayerische Motoren Werke
BNPL	Buy now, pay later
CAGR	Compound annual growth rate
CDC	Centres for Disease Control and Prevention
CFA	Communauté financière africaine
CIPESA	Collaboration on International ICT Policy for East and Southern Africa
CIPIT	Centre for Intellectual Property and Information Technology Law
CIS	Commonwealth of Independent States
CNFS	Climate and Nature Finance Strategy
CO_2	Carbon dioxide
Covid-19	Coronavirus disease 2019
CSIR	Council for Scientific and Industrial Research
CSP	Concentrated solar power
DFI	Development finance institution
DHL	Dalsey, Hillblom, and Lynn
DLP	Digital literacy programme
DPF	African Union Data Policy Framework
DRC	Democratic Republic of the Congo
DTT	Digital terrestrial television
ECA	United Nations Economic Commission for Africa
ED	Enterprise development
EGNC	Egypt Nanotechnology Center
EGP	Egyptian pound
ESCWA	United Nations Economic and Social Commission for Western Asia
ETA	Egyptian Tax Authority
EU	European Union
EVs	Electric vehicles
FAO	Food and Agriculture Organization
FDI	Foreign direct investment
FTRI	Frontier Technology Readiness Index
GB	Gigabyte
GDP	Gross domestic product
GenAI	Generative AI
GII	Global innovation index
GIS	Geographic Information System
GIZ	German International Cooperation Agency
GMV	Gross merchandise value
GPS	Global positioning system
GSMA	Global System for Mobile Communications Association
GW	Gigawatt
H&M	Hennes & Mauritz AB
HDI	Human Development Index
HIP	Hawassa Industrial Park

IAEA	International Atomic Energy Agency
IASS	Institute for Advanced Sustainability Studies
IBM	International Business Machines Corporation
ICE	Internal Combustion Engine and Electric Vehicles
ICT	Information and communication technology
ID	Identity document
IEA	International Energy Agency
IET	International Energy Transition
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
ILO	International Labour Organization
ILOSTAT	International Labour Organization's (ILO) central labour statistics database
IMF	International Monetary Fund
IOA	In on Africa
IoT	Internet of Things
IPPs	Independent power producers
IRENA	International Renewable Energy Agency
ISS	International Institute of Social Studies
ITU	International Telecommunication Union
JICA	Japan International Cooperation Agency
KEMRI	Kenya Medical Research Institute
KPMG	Klynveld, Peat, Marwick, and Goerdeler
LDCs	Least developed countries
LDVs	Light-duty vehicles
LP	Local projections
LP–SGMM	Local projections–system generalized method of moments
LSF	Lobu Small Stock Farm
LTE	Long-term evolution
MANSA	Managing African Networks for Sub-Saharan Assets
MASEN	Moroccan Agency for Sustainable Energy
MPI	Multidimensional Poverty Index
MTN	Mobile telephone networks
MW	Megawatt
Mwe	Megawatts Electrical
NEF	New Energy Finance
NEPAD	New Partnership for Africa's Development
NGS	Next-generation sequencing
NGS-SA	Network for Genomic Surveillance in South Africa
NLP	Natural language processing
NREP	National Renewable Energy Policy
OCP	Office Chérifien des Phosphates
ODA	Official development assistance
OECD	Organization for Economic Co-operation and Development
OEMs	Original equipment manufacturers.
OPEC	Organization of the Petroleum Exporting Countries (OPEC) and other major non-OPEC oil-exporting countries
PAPSS	Pan-African Payment and Settlement System
PHEV	Plugin hybrid electric vehicle
PPP	Public private partnerships
PV	Photovoltaic
PVH	PhillipsVan Heusen
QIPs	Quick impact projects
QR	Quick response
R&D	Research and development
RCS	Responsible cobalt solutions
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RFID	Radio frequency identification
RTGS	Real-time gross settlement
S&P	Standard & Poor's
S&T	Science and technology
SARS	South African Revenue Service

SARS-CoV	Severe Acute Respiratory Syndrome Coronavirus
SDG	Sustainable Development Goal
SDMX	Statistical Data and Metadata eXchange
SED	Socioeconomic development
SEZ	Atlantis Special Economic Zone
SHI	Social health insurance
SIM	Subscriber identity module
SMEs	Small and medium enterprises
SMRs	Small modular reactors
SMS	Short message service
SNA	System of National Accounts
STATNANO	Nano Science, Technology and Industry Information
STEM	Science, technology, engineering, and mathematics
STI	Science, technology, and innovation
STISA	Science, Technology, and Innovation Strategy for Africa
TETFund	Tertiary Education Trust Fund
TFP	Total factor productivity
TLIP	Trade Logistics Information Pipeline
TRADAR Club	Trade Intelligence and Regulations Club
TRT	Turkish Radio and Television Corporation Afrika
TW	Terawatt
TWh	Terawatt-hour
UHC	Universal health coverage
UIDAI	Unique Identification Authority of India
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
US	United States
US$	United States dollar
USA	United States of America
VAT	Value added tax
WBG	World Bank Group
WDI	World Development Indicators
WEF	World Economic Forum
WHO	World Health Organization
WIPO	World Intellectual Property Organization
ZLD	Zero-liquid-discharge

ACKNOWLEDGEMENTS

The 2026 edition of the *Economic Report on Africa* was prepared under the leadership of Claver Gatete, ECA's Executive Secretary, with guidance and close involvement of Hanan Morsy, Deputy Executive Secretary of ECA. The report team benefited from the guidance and supervision of Robert Lisinge, Director of Technology, Innovation, Connectivity and Infrastructure Division; Stephen Karingi, Director of the Macroeconomics, Finance and Governance Division; Samuel Kobina Annim, Director, African Centre for Statistics; Zuzana Schwidrowski, Director, Socio-Economic Development Division of ECA, Cosmas Milton Obote Ochieng, Director, Climate Change, Food Security and Natural Resources Division and Jean Luc Mastaki Namegabe, Director, Central Africa Sub-Regional Office..

The team that drafted the report was led by Hopestone Kayiska Chavula and Mactar Seck. The drafting team comprised Sidzanbnoma Nadia Denise Ouedraogo, Lerato Mary Litsesane, Ka Lok Wong, Yawovi Mawusse Isaac Amedanou, Torcia-Chanelle Banengai-Koyama, Jean-Marc Kilolo, Yohannes Hailu, Anthony Monganeli Mehlwana, Victor Konde, Aconkpanle Placide Colombe, Afework Temtime, Seleshi Tsige Teklegiorgis, Asfaw Yitna, Mariamawit Ayele, Bahta Bekele, Farah Farooq, Melat Haile, Bezawit Aragaw, Tinfissi-Joseph Ilboudo, Issoufou Seidou Sanda, Leandre Foster Ngogang Wandji, David Boko, Ali Yedan, Keiso Matashane-Marite, Judith Beatrice Auma Oduol, Syed T. Ahmed, Christian Oldiges, Amal Nagah Elbeshbishi, Jane Wangui Muthumbi, Marcellin Stephane Bella Ngadena, Omolola Mary Lipede, Atkeyelsh Persson, Lusungu Kayani, Giuseppe Tesoriere, Simon Mevel, Moukaila Mouzamilou Takpara, Jione Park, Laura Naliaka, Simon Mevel, Melaku Desta and Marit Kitaw. Special thanks go to this team for their collaboration, effort, diligence, and commitment in bringing this report to fruition.

Useful contributions were received from the following ECA staff who reviewed various parts of the Report led by Jean Luc Mastaki Namegabe:: Edna Akullq, Bineswaree Bolaky, Koffi Aseye Makafui Elitcha, Aboubakri Diaw, Bakary Dosso, Samia Hamouda, Soumaya Iraqui-Houssaini, Jane Karonga, Angela Kiconco, Andrew Mold, Rodgers Mukwaya and Mamoudou Sebego. This was made possible with support from the following Quality Assurance team from the Strategic Planning and Quality Assurance Division: Said Adejumobi, Sharon Chitambo, Mahelet Guoshe, Josephine Marealle Ulimwengu, and Inam Ullah.

The report was further enriched by valuable comments and suggestions from external experts including Salma Abbasi, Hany Besada, Juliet Chebet Moso, Laura Cyron, Charles Esimone, Sourafel Girma, Osman Issah, Nabil Jedlane, Nkem Khumbah, Wai Kit Si Tou, Wilhelmina Quaye, Sher Singh Verick, and Oluwarotimi Williams Samuel.

The report would not have been possible without the support provided by Omega Asheber Aberra, Marcel Bolboaca, Menkir Girma, Teshome Kifle, Fetsum Kurabachew, Sarah Mokeira, Robel Tsegaye, Solomon Wedere, and Mercy Wambui of ECA; Bruce Ross-Larson, Joe Caponio, Michael Crumplar, and Chris Trott of Communications Development for editing; Mandy Kabasa, Jeanne Penjan, Gretchen Reeves, and Carolina Rodriguez of Dilucidar for infographic design, and the French Translation and Editing Unit as well as the Text Processing Unit of ECA.

EXECUTIVE SUMMARY

GROWTH THROUGH INNOVATION: HARNESSING DATA AND FRONTIER TECHNOLOGIES FOR AFRICA'S ECONOMIC TRANSFORMATION

Africa has experienced steady economic growth in recent years, though it was mostly driven by factor accumulation, with negative contributions from productivity, suggesting limited improvements in efficiency. Growth failed to translate into robust structural transformation over time, as the reallocation of labour and capital from subsistence agriculture and other low-productivity activities to higher-productivity manufacturing and modern services have been slow.

Harnessing data and frontier technologies now offers significant opportunities for Africa to break from low-productivity activities and forge new pathways for inclusive and sustainable growth and to progress towards achieving the Sustainable Development Goals and Agenda 2063: the Africa We Want. Strategic adoption of frontier technologies across sectors can leapfrog traditional development pathways, raise efficiency, support industrial upgrading, increase productivity, attract investment, create jobs, and promote economic diversification.

Data as the new oil fueling frontier technologies have driven economic transformation worldwide. They hold immense potential to accelerate Africa's growth, innovation, and social development. How? By enabling more efficient decision-making, fostering entrepreneurship, economic inclusion and sustainability, and improving governance and service delivery.

Against this backdrop, the *Economic Report on Africa 2026: Growth through innovation: Harnessing data and frontier technologies for Africa's economic transformation* (ERA 2026) examines the impact of innovation on economic growth and development. It describes the role of frontier technologies in driving economic transformation, as well as the associated opportunities, risks, and challenges. It features the centrality of data and the new oil fueling frontier technologies and it highlights the actions that African countries can take to maximize the transformative potential of frontier technologies.

The report finds that enhancing Africa's sectoral productivity and closing productivity gaps through technology and innovation require differentiated strategies. Agriculture risks being left behind without climate-smart reforms, irrigation, and targeted finance. Manufacturing emerges as Africa's anchor for structural transformation through technology and innovation-enabled clusters and corridors. And services thrive on digitalization and finance, but Africa's human capital is too limited to sustain their growth. Institutions and regional cooperation are decisive for technology and innovation to flourish. Stronger governance, regulation, and public procurement can consolidate technological gains, while the African Continental Free Trade Area (AfCFTA) provides the scale to embed innovation in regional value chains.

ERA 2026 also details how frontier technologies are transforming Africa's production landscape, with their effects differing sharply across sectors. Productivity gains from frontier technologies in agriculture remain limited due to rainfed farming, low mechanization, weak research and development (R&D), and restricted digital access. In some contexts, digital adoption imposes short-term adjustment costs when new practices disrupt traditional production systems. Manufacturing is the most consistent beneficiary of frontier technologies, with digital automation, industrial clustering, and smart logistics generating scale economies and sustaining efficiency gains underpinning industrial diversification and structural transformation. For services, rapid and significant benefits arise from digitalization in telecommunications, fintech, logistics, and e-commerce. The ensuing innovation comes mainly through technology diffusion, adaptation, and new business models rather than formal R&D.

Frontier technologies such as artificial intelligence, machine learning, advanced data analytics, and photonic sensors are transforming production processes and service delivery across agriculture, healthcare, finance, energy, transport, and public services. Across Africa, smart agriculture is increasing yields while reducing input costs. Digital platforms are expanding access to markets and finance. Renewable energy technologies are extending electricity access to underserved regions. Electric vehicles are creating jobs and generating export earnings. And e-government services are improving efficiency and transparency.

Frontier technologies are also operationalizing the AfCFTA by integrating digital systems, such as the Pan-African Payment and Settlement System, which facilitates real-time cross-border payments and intra-African trade. They also present significant opportunities in extracting and producing Africa's critical minerals, which account for 30 per cent of the world's supply, and in producing green hydrogen and nuclear energy, essential for Africa's clean energy transition.

Despite these developmental benefits, frontier technologies carry such risks as displacing labour, widening social and economic inequality, skill mismatches, and gender gaps, particularly in economies with large informal sectors and limited absorptive capacity. Data sovereignty is another critical issue, as most of Africa's data are stored in foreign data centres, compromising national security and privacy, and worsening cybersecurity threats, technological dependencies, and supply chain disruptions. And Africa's incomplete data chains—with limited data centres, high processing costs, fragmented datasets, and weak integration—undermine data's value creation and local benefits. Governance and regulation issues are also prominent, as fragmented international cooperation and geopolitical tensions hinder technological advancements.

Amid these constraints, the report stresses that harnessing data and frontier technology to enable Africa's economic transformation requires many things. Strengthening governance structures. Forming partnerships. Promoting R&D, innovation, and entrepreneurship. Reforming the international financing environment. De-risking investment in frontier technologies. Developing inclusive and dynamic strategic policies, plans, and roadmaps. Promoting human capital development for the future. And investing in hard and soft infrastructure.

KEY MESSAGES

AFRICA'S GROWTH IS EXPECTED TO IMPROVE IN THE MEDIUM TERM

Economic growth is expected to reach 4.0 per cent in 2026, underpinned by rising infrastructure investments, stabilizing commodity prices, and increasing trade flows. Inflationary pressures are expected to ease thanks to declining food prices and stable currencies. But monetary policy will continue to diverge across countries and trade remains vulnerable to global shocks. The fiscal outlook continues to be favourable, amid external and domestic shocks. But debt service obligations remain high, constraining the fiscal space for development financing.

The pace of poverty reduction has been slow in Africa, despite some countries having reduced the number of both the multidimensional and monetarily poor. Most of these countries are Least Developed Countries, mostly in the Sahel and Central Africa. Poverty and inequality persist as development challenges, despite the progress of several countries towards widespread poverty reduction. Stubbornly wide gender gaps remain a major barrier to economic progress, and digital gender divides persist across most parts of Africa, with limited progress towards closing the gaps. Africa's input-driven growth model has thus proven inadequate for countries to exploit the opportunities emanating from technology and innovation.

Closing the productivity gaps through technology and innovation is proving to be the promising path to resilient and sustainable growth. Frontier technology readiness can deliver delayed but lasting dividends for African countries. Unlike broad innovation inputs that yield only short-lived gains, technology and innovation generate sustained productivity and income growth, with effects compounding over time.

The economic impact of frontier technologies and innovation depends on complementary capabilities that enable absorbing, adapting, and scaling technologies. Skills, industrial capacity, digital and physical infrastructure, institutional quality, and access to finance—all shape whether technological advances translate into economywide productivity gains. Skills and industrial upgrading are found to be consistent drivers of productivity and output, while ICTs provide short-term boosts. Financial systems, however, need to be reoriented through facilities such as innovation bonds, blended finance facilities, and regional credit lines to channel resources into high-productivity sectors. Africa's policy emphasis should shift from "digital expansion" alone to ecosystem readiness, especially skills and productive capabilities, to convert technological diffusion into sustained productivity gains.

DESPITE THE INCREASING INVESTMENT, STRUCTURAL WEAKNESSES CONTINUE TO LIMIT TECHNOLOGY AND INNOVATION PROGRESS

Governments and private sector actors continue to invest in technologies that have the potential to address unique development challenges facing African countries, in areas including health, financial inclusion, education, and food security. Despite such policy frameworks as the African Union's 1 per cent target and the establishment of national science and innovation funding initiatives, ERA 2026 highlights how structural weaknesses limit technology and innovation progress for African countries and fail to generate immediate productivity gains and growth.

DATA ARE ASSETS, SOURCES OF REVENUE, AND BUSINESS OPPORTUNITIES FOR AFRICAN ECONOMIES

Data have become a critical economic asset, driving economic transformation worldwide. They thus hold immense potential to accelerate growth, innovation, and social development by enabling more efficient decision-making, fostering entrepreneurship, and improving governance and service delivery. As data move through their lifecycle of generation, storage, processing, analysis, and economic impact, increasing value is created at each stage, making it a new stream of revenue for industries that have data as part of their business portfolio. Data are thus a

defining resource in the digital era—the "new oil" that is renewable and multiplies in value when analysed and shared.

Clean energy technologies enable more reliable and sustainable power supplies for industry and households, thus fostering new business models and rural electrification. These technologies have improved manufacturing processes, streamlined logistics, reduced operational costs, and brought greater transparency to trade, thus strengthening the competitiveness of local industries and supporting inclusive economic growth.

AFRICA HAS A COMPARATIVE ADVANTAGE IN DEVELOPING FRONTIER TECHNOLOGIES

With 30 per cent of the world's critical mineral reserves and 60 per cent of its best solar resources, Africa has a demonstrable comparative advantage to capture a meaningful share of the growing market for frontier technologies but must leverage them effectively. By localizing production and increasing participation in the local, regional, and global value chains, countries can drive forward with green industrialization. To do this requires a skilled workforce, but Africa has a comparative demographic advantage thanks to its young population, which tends to be more adaptive and creative.

KEY RECOMMENDATIONS

To maximize the transformative potential of data and frontier technologies in Africa, governments should:

STRENGTHEN GOVERNANCE OF FRONTIER TECHNOLOGIES

Governance of frontier technologies should maximize their benefits while minimising associated risks, considering each country's national plans, priorities, and aspirations. This involves establishing responsive legal, regulatory, and administrative frameworks, along with strong institutions to oversee their implementation. Cybersecurity remains a high-risk factor as many African countries lack basic IT infrastructure to fight cybercrime. These deficits emphasise the urgent need to monitor, prevent, investigate, and prosecute cybercrimes.

FOSTER PARTNERSHIPS FOR ADVANCING FRONTIER TECHNOLOGIES

Partnerships are important for expanding funding, talent, and infrastructure to share the risks of failure and navigate complex market-entry rules. National, regional, and international partnerships need to be collectively developed and agreed upon by stakeholders, including the government, industry, and civil society. As the costs of R&D, infrastructure, and technology acquisition increase, such alliances can meet the demands of many frontier technologies as well as to reduce costs associated with accessing those technologies, especially for poorer countries.

PROMOTE RESEARCH, DEVELOPMENT, INNOVATION, AND ENTREPRENEURSHIP

Frontier technologies are driven by R&D to create new products and services, and significantly enhance existing ones. They enable companies to become more competitive by increasing funding, creating centres of excellence in frontier technology development and adaptation. Africa's gross R&D expenditure across all sectors accounted for only about 1.3 per cent of the global total in 2023, mostly by the public sector rather than industry. African countries now need to increase R&D funding, create centres of excellence in frontier technologies development and adaptation, and improve the policy and regulatory environment for commercializing, seeding and attracting technology startups.

FORMULATE INCLUSIVE AND STRATEGIC POLICIES, PLANS, AND ROADMAPS

This should be based on research and scientific evidence and directly connected to industrialization, economic diversification, job creation, and national ownership. Policies must remain flexible, adaptable, and responsive to emerging trends and unforeseen challenges. They must also be inclusive in their design and implementation to take care of diverse interests, concerns, opportunities, and risks across different societal groups.

DEVELOP HUMAN CAPITAL FOR THE FUTURE

Current estimates indicate that only 13 per cent of African children can read and understand a simple story by the age of 10; just 15 per cent of all students in upper secondary are enrolled in technical and vocational education training, and the gross enrolment rate in tertiary education is 9 per cent, compared with 42 per cent globally. Broadening access and enhancing performance are urgently needed to empower the population, especially youth and women, with the technology, entrepreneurial, creative, and problem-solving skills to use, design, and produce knowledge products. Countries need comprehensive national education action plans that include prioritizing context-specific strategies for curriculum reform and the professional development of teachers, with a focus on practical skills. Establishing structured collaboration frameworks between universities and industry can ensure that education—particularly in science, technology, engineering, and mathematics—is aligned with industry and national needs.

INVEST IN HARD AND SOFT INFRASTRUCTURE

High-performance computing facilities, cloud computing platforms, and 5G networks are essential for enabling widespread digital technology use. Africa's infrastructure deficit, along with its data sovereignty challenges, must be addressed. The huge energy requirements of data centres make the joint investment in data centres and energy generation an appealing financing option. Data centres can guarantee the offtake of energy generated. Investments in science, technology, and industrial parks can support the commercialisation of emerging innovations. And electric vehicle charging stations can facilitate the mass adoption of clean transportation solutions. But the success of these advanced systems relies heavily on traditional infrastructure, such as dependable energy, transport, and communication networks.

REFORM THE INTERNATIONAL FINANCING ENVIRONMENT

Structural features of the international financing environment increasingly constrain investment in R&D, innovation, and entrepreneurship, including improvements in sovereign debt resolution frameworks, the international credit-rating ecosystem, and the global tax architecture. Reforms to these global systems can address persistent financing challenges and revenue leakages, thus reducing reliance on costly external borrowing.

DE-RISK INVESTMENT IN FRONTIER TECHNOLOGIES

Investing in frontier technologies entails a significant risk, particularly during the early stages of R&D. The risks are pronounced for smaller firms and startups, which lack the financial resilience to absorb potential losses. Providing tax incentives or offering loan guarantees can provide partial or complete credit protection against a project's failure by encouraging lending and investment in high-risk ventures.

IN SUM

Africa's economic growth has mostly been driven by factor accumulation—increases in land use, capital, and labour—rather than by genuine gains in productivity. With notable technological adoption and significant potential for rapid scaling, data, frontier technologies and innovation offer significant opportunities for African nations to transform their economies through boosting productivity, creating jobs, fostering economic diversification, and strengthening global competitiveness.

With its youthful population, abundant critical minerals, and unmatched hydro and solar power potential, Africa is uniquely positioned to claim a defining share of the technology-driven future. Technologies from green hydrogen to small nuclear reactors and integrated renewable grids can power industries, data centres, and regional electricity markets. Digital payment systems and mobile money can strengthen cross-border payments and intra-African trade, expanding financial inclusion, strengthening regional integration, and creating opportunities for entrepreneurship and micro, small, and medium enterprises. And data and frontier technologies can enhance transparency, boost efficiency, and sharpen the continent's competitiveness in the global market.

CHAPTER 1 RECENT ECONOMIC AND SOCIAL DEVELOPMENTS

Africa's economic growth for 2026 is estimated at 4.0 per cent, underpinned by public investment and fiscal reform. Services continue to dominate sectoral contribution to growth, with technology and innovation playing key roles. Technological advancements have increasingly driven economic growth through enhanced financial inclusion, education, entrepreneurship, governance, and access to services. Inflationary pressure is anticipated to ease in the medium term, supported by declining food prices and stable currencies. But monetary policy will continue to vary across countries due to inflation, policy uncertainty, and domestic currency movement.

The 2026 fiscal outlook for Africa remains favourable amid external and domestic shocks, reflecting fiscal consolidation efforts through spending rationalization and enhanced domestic revenue mobilization. But debt service obligations remain high, because the bulk of Africa's debt is denominated in foreign currencies, which increases vulnerability to external shocks, including exchange rate fluctuations.

Poverty and inequality remain persistent development challenges in Africa, despite progress towards poverty reduction in several countries. The same is true with the continent's rapid urbanization, which has not consistently translated into broad-based social development—despite its contribution to social and economic transformation. Gender gaps remain a major barrier to economic progress as digital gender divides persist across most of Africa. Unlocking the continent's full human capital requires prioritizing comprehensive strategies that address the root causes of inequality and enable meaningful participation in the technology-driven future.

Enhancing productivity and growth and harnessing data and frontier technologies[1] through innovation could drive meaningful economic progress and development. Technological adoption in Africa has gained traction and has great potential for rapid scaling and positive externalities in other sectors.

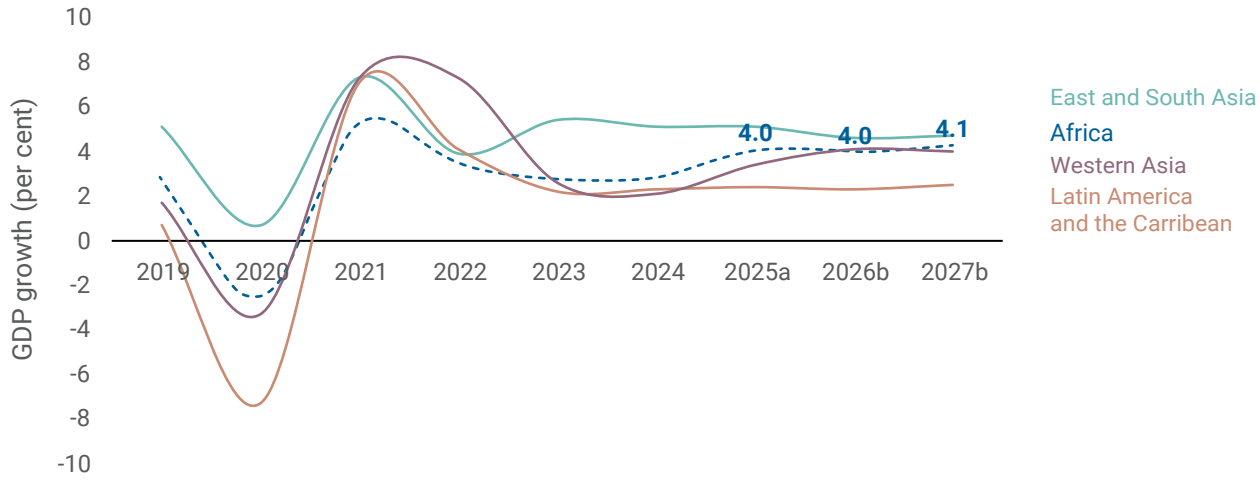
RECENT ECONOMIC PERFORMANCE

GROWTH PERFORMANCE IS EXPECTED TO IMPROVE IN 2026–2027, SUPPORTED BY PUBLIC INVESTMENT

Africa's real gross domestic product (GDP) growth rebounded to an estimated 4.0 per cent in 2025 but will remain unchanged in 2026 before increasing to 4.1 per cent in 2027. This exceeds the 2026 growth rate in Latin America and the Caribbean (2.3 per cent) but lags that in East and South Asia (4.6 per cent) and Western Asia (4.1 per cent) (figure 1.1). Growth in Africa is supported by improved macroeconomic stability, especially in large economies, as well as stronger public investment and consumer spending. But external challenges remain, including geopolitical tensions and domestic disruptions in the aftermath of elections in some countries. Through fiscal consolidation, some countries have streamlined spending and prioritized capital spending to foster long-term sustainable economic growth. That strategic infrastructure investment—for example, Egypt's high-speed rail network, Kenya's Konza Technopolis, and Nigeria's Lagos Free Trade Zone—has contributed substantially to growth.[2] These projects not only enhance economic connectivity but also attract critical foreign direct investment (FDI), reflecting improved investor confidence.

Africa's real gross domestic product (GDP) growth rebounded to an estimated 4.0 per cent in 2025 but will remain unchanged in 2026 before increasing to 4.1 per cent in 2027.

Figure 1.1 GDP growth, by developing region, 2019–2027

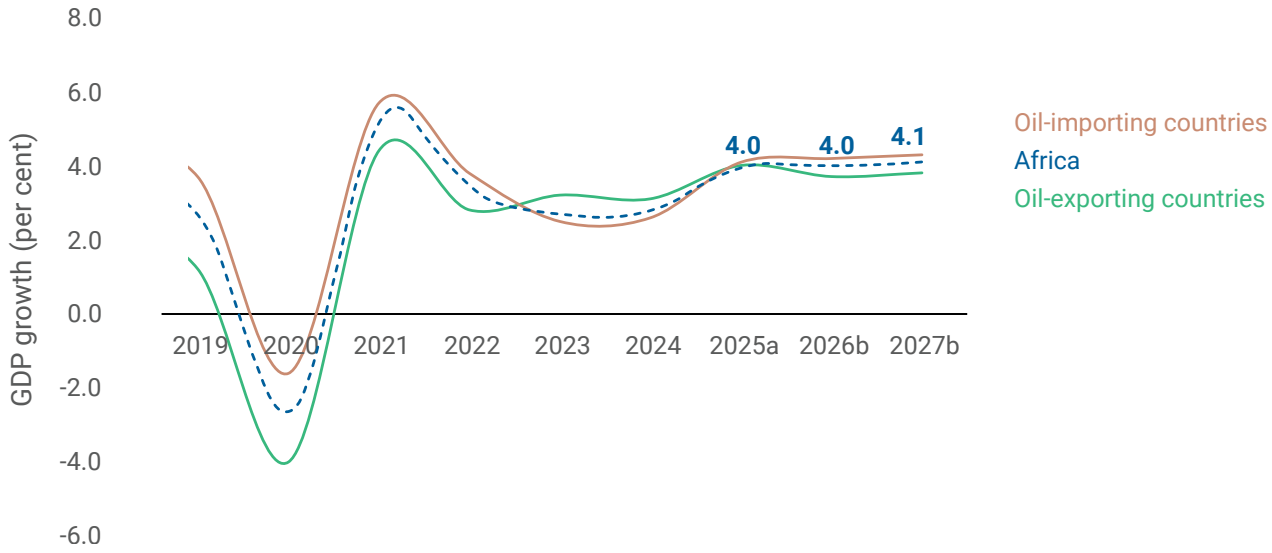


a. Estimated. b. Projected.
Source: United Nations 2026.

Despite overall GDP growth recovery in Africa in 2025, oil-importing countries and oil-exporting countries diverged.

Despite overall GDP growth recovery in Africa in 2025, oil-importing countries and oil-exporting countries diverged (figure 1.2). Growth in oil-importing countries was supported by the decline in the price of crude oil—which fell to $64 per barrel in November 2025 from $79 in January 2025, following global uncertainties due to United States tariffs and weaker-than-expected demand in Brazil, China, and India.[3] But the decline in oil prices is expected to negatively impact Africa's major oil-exporting countries, particularly crude oil exporters (Algeria, Angola, and Nigeria). For most oil-exporting countries, petroleum products account for more than 80 per cent of total exports, exposing them to heightened volatility and uncertainty.[4] Expectations of higher global demand, combined with a projected increase in oil production by the Organization of the Petroleum Exporting Countries and non-member oil-producing countries (OPEC+), would exert further downward pressure on oil prices, hence the improved inflation outlook, especially in oil-importing countries.[5] Growth in oil-exporting countries is thus projected to decline from an estimated 4.0 per cent in 2025 to 3.7 per cent in 2026, underpinned by the expected lower oil prices and a possible market surplus due to OPEC+'s expected production increase. The fragile political situations in Libya, South Sudan, and Sudan may also weigh negatively on the overall outlook of oil-exporting countries.

Figure 1.2 GDP growth in Africa, by economic grouping, 2019–2027

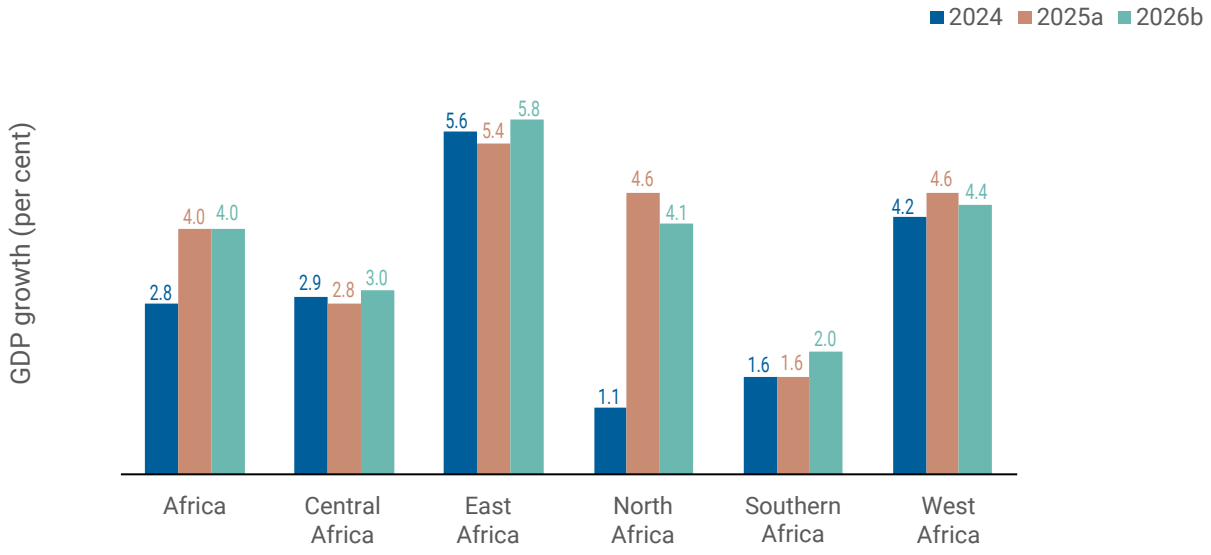


a. Estimated. b. Projected.
Source: United Nations 2026.

EAST AFRICA LEADS SUBREGIONAL GROWTH

Growth varied across subregions in 2025. East Africa is the fastest growing, at an estimated 5.4 per cent in 2025 and a projected 5.8 per cent in 2026 (figure 1.3), driven by strong growth in Djibouti, Ethiopia, Rwanda, Tanzania, and Uganda and bolstered by continued domestic demand, strong infrastructure investment, and robust performance in the agriculture and mining sectors.[6] But conflicts in eastern Democratic Republic of the Congo, Madagascar, and South Sudan remain the subregion's most pressing issue.

Figure 1.3 GDP growth in Africa, by subregion, 2024–2026



a. Estimated. b. Projected.
Source: United Nations 2026.

West Africa is projected to grow at an average of 4.5 per cent in 2025–2026, with Senegal growing fastest, at an average of 7.5 per cent, followed by Niger at 7.1 per cent and Guinea at 6.6 per cent. Senegal's economic growth is driven by the hydrocarbons sector, favourable economic conditions (including low inflation), and the government's transformation agenda. That agenda focuses on fostering FDI, achieving a digital transformation that ensures effective government administration and public service delivery, closing the digital divide, and supporting innovation and entrepreneurship.[7] Economic growth in Niger is driven by high oil production and exports, as well as stronger domestic demand.[8] The mining industry and agriculture drive Guinea's economic growth, which has not been inclusive: the national poverty rate remains at 52 per cent.[9] The subregion's largest economy, Nigeria, is projected to grow by 3.8 per cent in 2026, driven by higher oil production and a robust services sector and supported by domestic reform gains.[10] Despite a slight shift in the country's economic structure after rebasing GDP figures to a base year of 2019, services still remain the dominant sector.[11]

The economic outlook for North Africa remains robust in the near term, with real GDP growth projected to rise by an average of 4.4 per cent in 2025–2026, driven by increasing energy production in Algeria; rich natural resources, expanding extractive industries, and the growing services sector in Mauritania; strong recovery in agricultural output and construction and higher household consumption in Morocco; and tourism receipts and remittances inflows in Tunisia.

Frontier technologies and innovation have high potential to accelerate the transformation of Africa's services sector and to increase their contribution to GDP.

The recovery in oil production and infrastructure investment in Libya is expected to boost the subregion's economic performance, though the civil war in Sudan continues to weigh on it.

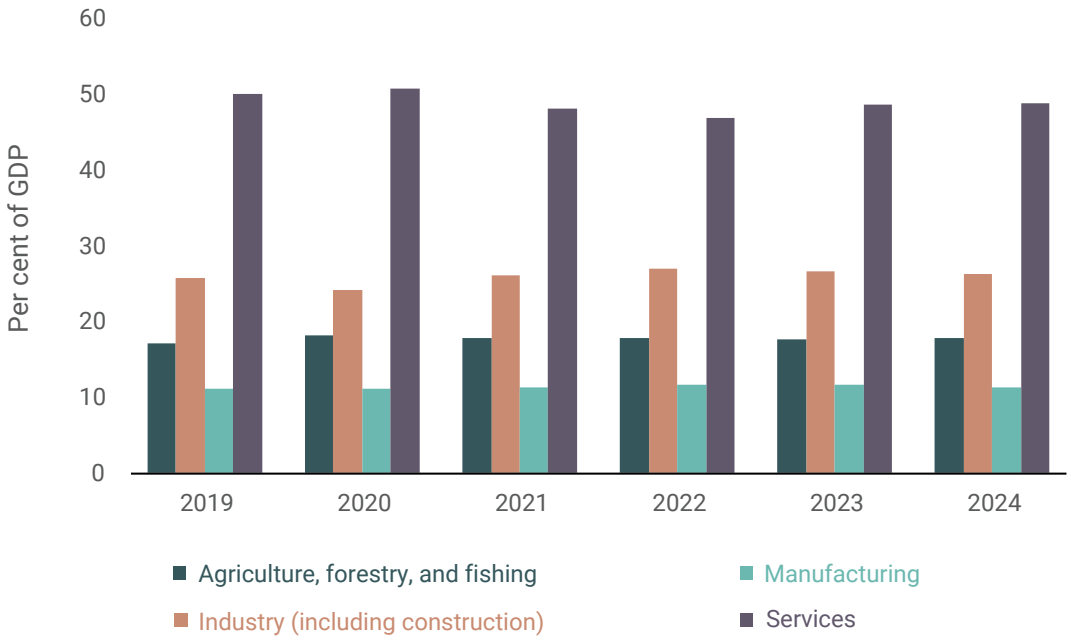
Central Africa's growth is projected to rise from an estimated 2.8 per cent in 2025 to 3.0 per cent in 2026, driven by increased infrastructure investment (digital and transport), improved governance and institutions, macroeconomic stability (fiscal and monetary policy), natural resources (agriculture and energy), and urbanization, led by Cameroon, the Central African Republic, and Chad.[12] Despite being on the rise, Central Africa is considered one of the lowest performing subregions on the continent, just above Southern Africa.

Southern Africa's growth is projected to be 1.9 per cent in 2025–2027, following steady growth of 1.6 per cent since 2024. Growth in the subregion's largest economy, South Africa, remained subdued at an estimated 1.0 per cent in 2025 but is projected to reach 1.4 per cent in 2026 and 1.7 per cent in 2027. Energy disruptions, water shortages, and extreme weather continue to weigh on the country's growth performance.[13] Zambia (at 4.9 per cent) and Zimbabwe (at 4.2 per cent) are projected to lead the subregion's growth in 2026, driven by improvements in mining and agriculture, as well as strong agricultural performance and commodity prices.[14]

SERVICES CONTINUE TO DOMINATE GDP, WITH TECHNOLOGY AND INNOVATION PLAYING A KEY ROLE

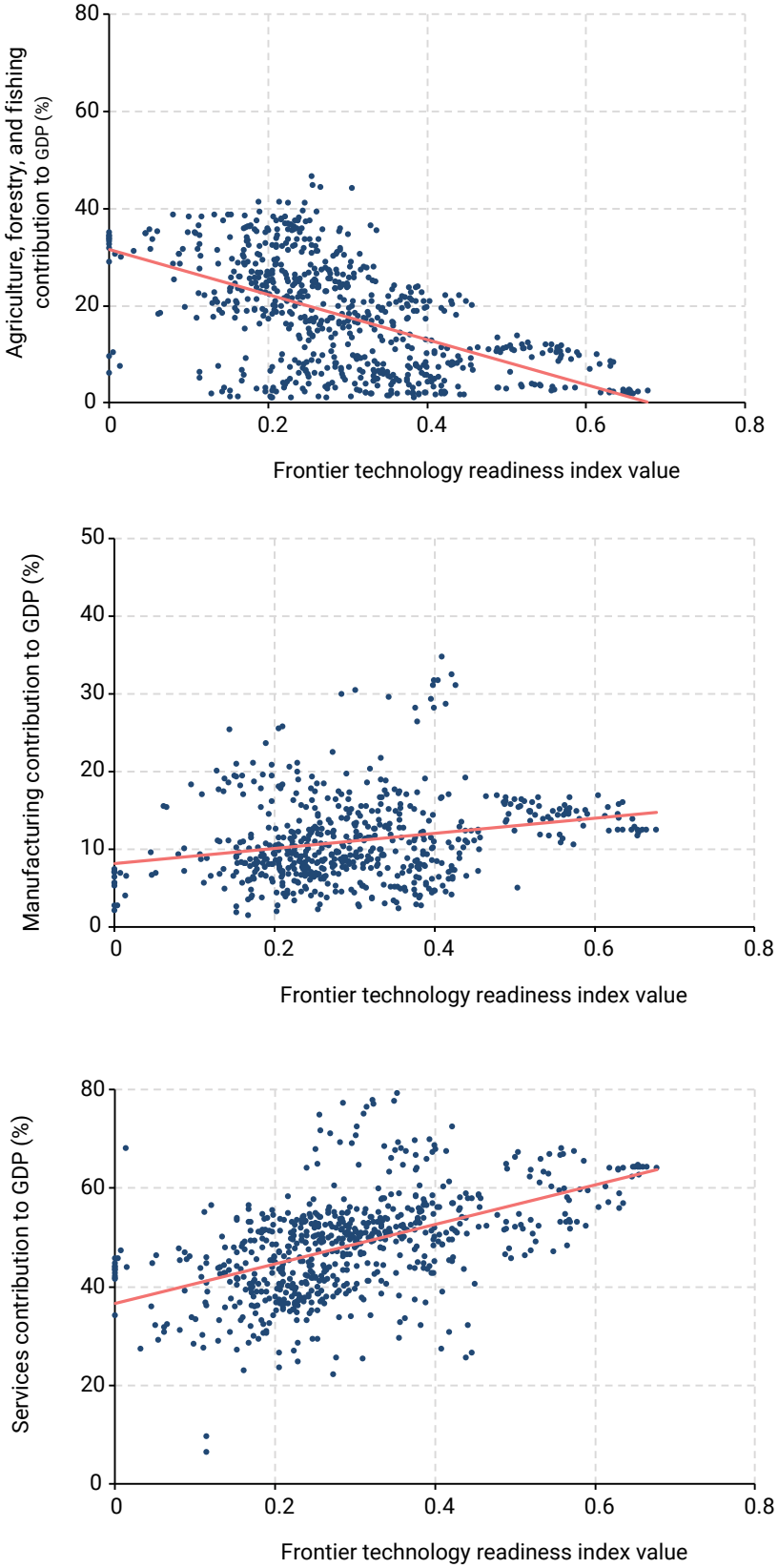
The services sector continues to dominate in Africa's output, accounting for 48.8 per cent in 2024, followed by industry (26.2 per cent), including manufacturing at 11.3 per cent, and agriculture (17.9 per cent) (figure 1.4). Frontier technologies and innovation have high potential to accelerate the transformation of Africa's services sector (as well as the manufacturing sector) and to increase their contribution to GDP because the services sector is still dominated by traditional services in most African countries (figure 1.5).[15] At the same time, most economies are agriculture dependent and thus need policy strategies and investment to leverage frontier technologies and innovation while taking into consideration the effects of climate change to increase agricultural productivity (chapter 2).

Figure 1.4 Sectoral contribution to GDP in Africa, 2019–2024



Source: ECA calculations based on United Nations (2025) UNData.

Figure 1.5 Relationship between technology readiness and sectoral contribution to GDP in Africa, 2010–2024



Source: ECA calculations based on United Nations Conference on Trade and Development (2025c) and World Bank (2025h).

The low impact and uptake of frontier technologies and innovation on some economic sectors may underscore the need for greater technological investment (figure 1.6). Strategic investment in digital infrastructure and inclusive digital policies and reforms have brought large economic and social benefits to many African countries recently. Technological advancements have increasingly driven economic growth through enhanced financial inclusion, education, entrepreneurship, governance, and access to service (chapter 3). These efforts have increased the contributions of the information and communications technology (ICT) sector to GDP, boosted financial inclusion, improved efficiency in public services, and raised FDI in Ghana, Kenya, Mauritius, Morocco, and South Africa. Full fibre-optic connectivity and the development of eGovernment platforms have fostered a robust ICT business process outsourcing sector that contributes 5.8 per cent to Mauritius's GDP and has created jobs. In South Africa, digital infrastructure initiatives have supported the growth of the ICT and financial technology sectors, which are projected to contribute 15–20 per cent to GDP by 2025, up from 8–10 per cent in 2020, thereby boosting job creation, financial inclusion, and productivity.[16]

In Kenya, infrastructure expansion, supportive policy frameworks, and financial innovation (particularly M-Pesa) have broadened access to financial services; supported small and medium-size enterprises with access to credit and business management tools; and promoted easy, fast, and secure cashless transactions.[17] Adopting digital technologies across agriculture, manufacturing, transport, and trade is expected to contribute to GDP, create hundreds of thousands of jobs, and generate substantial tax revenue by 2028.[18] In Ghana, the ICT sector's contribution to GDP rose from GHS 4.4 billion in 2016 to GHS 21 billion in 2022, to account for approximately 4 per cent of GDP. Digital financial services, especially mobile money, have boosted economic inclusion, increasing GDP by 8–10 per cent and income per capita by around $530 at the end of 2023.[19] Skills development, improved industrial activity, and access to finance, coupled with effective institutions and regional cooperation, have been the key drivers of productivity and overall growth among African countries (chapter 2).

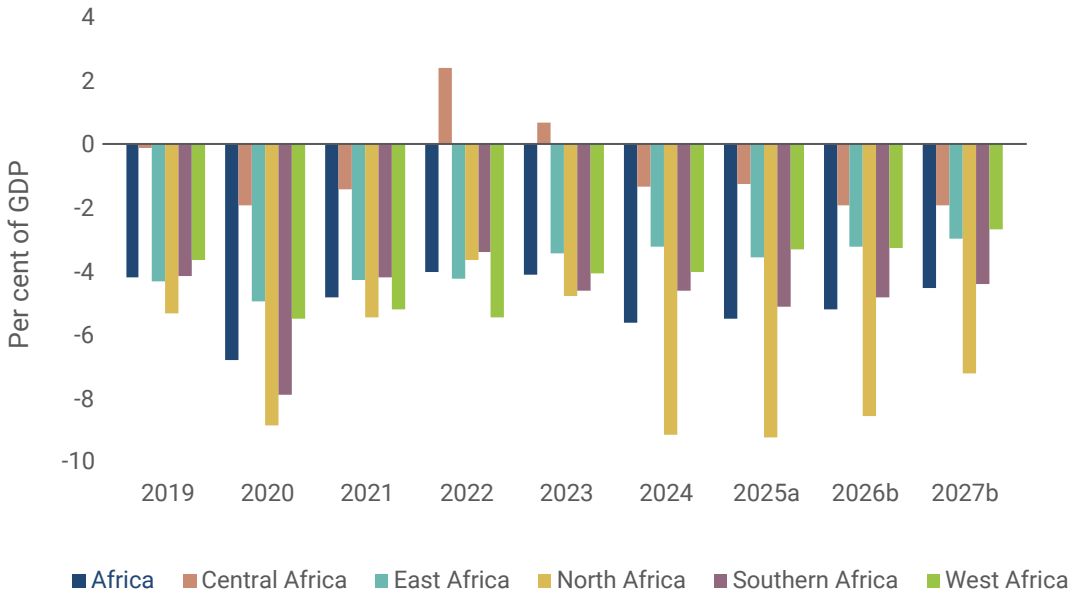
FISCAL IMBALANCES AMID HIGH UNCERTAINTY

African countries have grappled with considerable fiscal pressure in the aftermath of the Covid-19 pandemic, as they manage large public debt burdens, high interest rates, and growing public spending demands. Fiscal space remains constrained, driven by persistent debt vulnerabilities, elevated borrowing costs, and subdued global economic activity. Consequently, many governments are expected to pursue tighter fiscal policies to narrow budget deficits and reduce debt burdens.

The average fiscal deficit is projected to return to pre-pandemic levels in 2025–2026 as countries gradually consolidate their fiscal positions through spending rationalization and enhanced domestic revenue mobilization.[20] Many African countries have adopted electronic tax filing and payment systems, which have improved the efficiency and effectiveness of tax administration and boosted tax collection.[21] They have also adopted biometric technology to ensure that public programmes are well targeted and have better coverage, optimizing government spending.[22] But fiscal incentives and other direct government initiatives are not mobilized enough to support frontier technologies. The average overall fiscal deficit is projected to narrow from an estimated 5.5 per cent of GDP in 2025 to 5.2 per cent in 2026 and 4.5 per cent in 2027 (figure 1.6). This performance is supported by fiscal consolidation, supplemented by reduced fiscal pressure in Ethiopia, Ghana, and Zambia, where ongoing debt restructuring has been accompanied by austerity measures.[23] The improving fiscal balance in 2026 reflects the projected increase in government revenue, in line with the expected pickup in economic growth, which will outpace the rise in non-interest government spending.[24]

The average overall fiscal deficit is expected to narrow from an estimated 5.5 per cent of GDP in 2025 to 5.2 per cent in 2026 and 4.5 per cent in 2027, supported by fiscal consolidation efforts.

Figure 1.6 Fiscal deficit (general government net lending or borrowing) in Africa, by subregion, 2019–2027



a. Estimated. b. Projected.
Source: ECA calculations based on IMF (2025a).

Official development assistance (ODA) has long played an important role in supporting development programmes and both the external and fiscal positions of many African countries. But ODA to Africa has seen a heavy downturn recently, from a peak of $80.2 billion in 2020 to $71.8 billion in 2024.[25] Globally, ODA declined by an estimated 9–17 per cent in 2025, amplifying the continent's fiscal vulnerabilities. The health and education sectors are most affected by ODA cuts because they are the main focus of donors. This threatens fiscal sustainability, which may reverse development gains, including in health and education, and exacerbate poverty, food security, and humanitarian crises.[26] In the face of declining ODA, Algeria and Egypt have embarked on a digital transformation for effective tax administration, diversified revenue sources, and implemented public financial management reforms.[27] Ethiopia is restricting spending by gradually phasing out quasi-fiscal activities through subsidy reforms, while Uganda is working towards modernizing tax administration and fighting tax evasion using the Electronic Fiscal Receipting and Invoicing Solution.[28] However, challenges ranging from structural constraints to fragile political situations limit some countries' ability to generate sufficient domestic funds to finance inclusive and sustainable development.[29]

All subregions except Central Africa are projected to narrow their fiscal deficit in 2026. North Africa has the largest deficit, at an estimated 9.2 per cent of GDP in 2025 and a projected 8.6 per cent in 2026 (see figure 1.6). In Morocco, the widening deficit is underpinned by the government's pledge to raise wages, infrastructure investment spending, and social spending associated with the continuing reforms.[30] In Algeria, the elevated fiscal deficit is due to lower expected hydrocarbon revenue, which will outweigh fiscal consolidation efforts.[31] Southern Africa follows with the deficit projected to widen from 4.6 per cent of GDP in 2024 to 4.8 per cent in 2026, due mainly to surging debt servicing costs that are constraining the subregion's fiscal space.

In East Africa, the average fiscal deficit increased slightly, from 3.2 per cent of GDP in 2024 to an estimated 3.5 per cent in 2025, but is projected to decrease to 3.2 per cent in 2026. The modest deterioration reflects the envisaged high government spending in some countries—such as Rwanda,

Overall, Africa's fiscal position remains highly vulnerable to both external and domestic shocks, constraining governments' ability to effectively manage public finances and undermining their ability to respond to shocks.

which is investing in large-scale infrastructure projects, including the ongoing construction of Bugesera International Airport and the expansion of the national air carrier, RwandAir. Uganda may also see higher spending in 2026 as it prepares for the January elections, while Tanzania has a higher budget allocation for improving sports, transport, and hospitality infrastructure. The projected fiscal improvement in 2026 is attributed to fiscal consolidation efforts in such countries as Ethiopia, which is striving to meet its International Monetary Fund (IMF) programme targets,[32] and Kenya, which is consolidating its fiscal position without an IMF programme.

In Central Africa, the fiscal deficit remained steady at an estimated 1.9 per cent of GDP in 2025, the lowest average fiscal deficit across subregions in 2025 and 2026. This is attributed largely to a resurgence in economic activity, supported by favourable global commodity prices—notably for crude oil, natural gas, minerals, and other primary exports.[33] Cameroon and Chad are under IMF programmes that are associated with fiscal discipline and sustainability.[34]

By contrast, West Africa is projected to improve its fiscal position by narrowing its deficit from 4.0 per cent of GDP in 2024 to 3.3 per cent in 2026, driven by fiscal consolidation efforts in most of the subregion's countries. Nigeria's fiscal performance is buoyed by the government's ongoing commitment to policy reforms implemented in 2023, including removing fuel subsidies. Ghana's improved fiscal performance is supported by an IMF programme and debt restructuring, like the Gambia, which is supported by a new IMF programme to strengthen macroeconomic fundamentals and institutional efficiency.[35]

Overall, Africa's fiscal position remains highly vulnerable to both external and domestic shocks, constraining governments' ability to effectively manage public finances and undermining their ability to respond to shocks. Fiscal rules can play a vital role in promoting fiscal sustainability by offering a sound framework for budgeting and debt management. But despite adopting fiscal rules, many African countries still struggle with enforcement (table 1.1). Striking a balance between fiscal discipline and growth-oriented public spending remains a critical challenge amid constrained fiscal space.

Table 1.1 Fiscal management performance in selected African countries, by fiscal rule, 2016–2025 (per cent of GDP)

	Ceiling	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025[a]
Debt rule[a]											
Burundi	50	46.1	46.9	53.0	60.1	65.9	66.5	68.3	47.2	43.2	35.3
Congo	70	84.6	88.5	71.2	77.6	102.5	97.8	92.5	99.0	95.4	91.4
Kenya	50	50.4	53.9	56.4	59.1	68.0	68.2	67.8	73.0	65.6	68.3
Namibia	35	45.8	43.8	48.7	57.6	64.3	69.6	69.4	67.2	67.7	63.9
Rwanda	50	41.1	45.6	49.2	53.6	68.7	67.3	60.9	63.4	67.2	77.6
Tanzania	50	39.8	40.1	42.0	40.4	41.3	43.4	44.9	47.4	48.2	47.1
Uganda	50	31.3	33.6	34.9	37.5	46.3	50.3	50.2	50.2	51.8	54.0
Budget balance rule[b]											
Burundi	3	-7.1	-5.0	-6.7	-6.4	-6.3	-5.2	-10.6	-7.4	-5.0	-6.5
Kenya	3	-7.5	-7.4	-6.9	-7.4	-8.1	-7.2	-6.1	-5.7	-5.5	-5.4
Nigeria	2.5-3	-4.6	-5.4	-4.3	-4.7	-5.6	-5.5	-5.4	-4.2	-3.4	-4.5
Rwanda	3	-2.3	-2.5	-2.6	-5.1	-9.5	-7.0	-5.7	-5.0	-6.6	-6.3
Uganda	3	-2.6	-3.8	-3.0	-4.8	-7.8	-7.4	-6.0	-4.9	-5.8	-6.7

a. Estimated.
a. The debt ceiling is set at 50 per cent of GDP for countries in the East African Community and at 70 per cent of GDP for countries in the the Central African Economic and Monetary Community.
b. The fiscal deficit ceiling is set at 3 per cent for countries in the East African Community and at 3.0 per cent of GDP for 2007–2022 at 2.5 per cent of GDP since 2023 in Nigeria.
Source: IMF 2022, 2025a.

PUBLIC DEBT REMAINS ELEVATED AMIDST GROWING DEBT SERVICE BURDEN

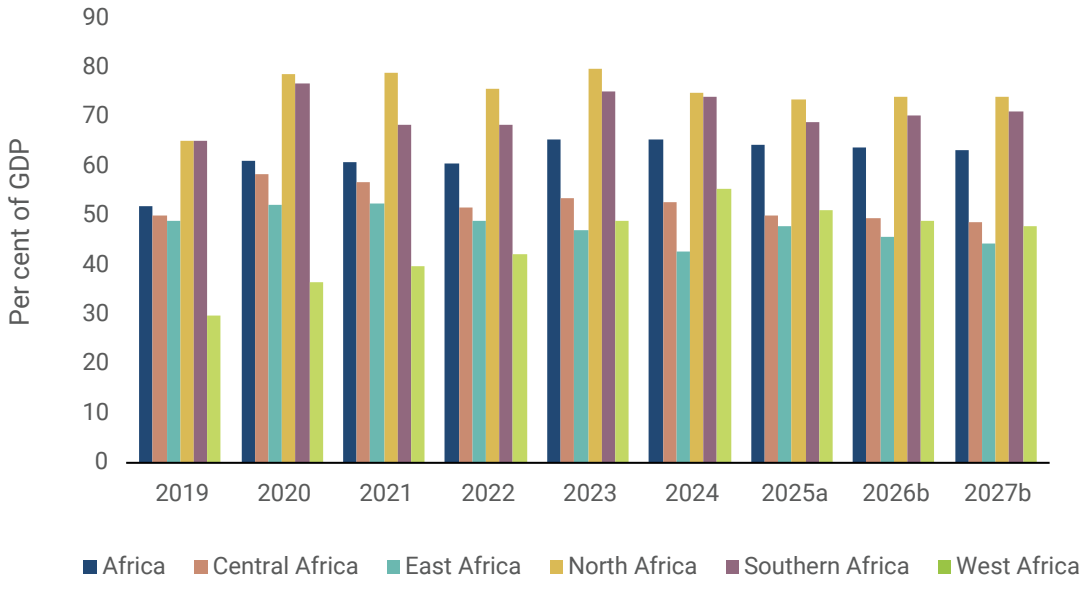
Due to sustained fiscal consolidation efforts across many African countries, public debt ratios have broadly stabilized but remain far above pre–Covid-19 pandemic levels. Debt service obligations continue to be high, constraining fiscal space for climate and development financing. Many African countries dedicate a larger share of their budget to interest payments than to health, education, or investment in development. During 2021–2023, African countries spent $70 per capita on interest payments, $44 per

Beyond easing access to international capital markets, African countries must strengthen fiscal discipline and foster a conducive environment for investment to develop domestic capital markets, especially local currency bond markets and local currency eurobonds.

capita on health, and $63 per capita on education. More than half of Africa's people live in countries where interest payments exceed development spending, exacerbating their vulnerable situation.[36] In addition, more than half of Africa's external debt is denominated in US dollars, which exposes the continent to exchange rate risks and high borrowing costs. For Angola, Ethiopia, Ghana, Nigeria, South Africa, and Zambia, more than 80 per cent of external debt is denominated in US dollars.[37] The continent's average debt-to-GDP ratio is projected to decline marginally from 65.3 per cent in 2024 to an estimated 64.2 per cent in 2025, 63.5 per cent in 2026, and 63.0 per cent in 2027 (figure 1.7). But these averages mask considerable variation across countries, with debt remaining particularly high in several economies.

The continent's average debt-to-GDP ratio is projected to decline marginally from 65.3 per cent in 2024 to an estimated 64.2 per cent in 2025, 63.5 per cent in 2026, and 63.0 per cent in 2027.

Figure 1.7 Gross government debt in Africa, by subregion, 2019–2027



a. Estimated. b. Projected.
Source: ECA calculations based on IMF (2025a).

Stabilizing debt indicators has been facilitated by easing global financial conditions, the gradual post-pandemic economic recovery, and fiscal consolidation in most countries. After two years of restricted access to international capital markets and heightened debt servicing costs, African countries have seen sovereign bond spreads narrow. This has enabled Benin, Côte d'Ivoire, Kenya, and Senegal to return to international markets with new bond issuances.[38] African countries' participation in international capital markets has been associated with macroeconomic instability, low international reserves, declining ODA and concessional financing, tight domestic capital markets, and thus a means of diversifying financing sources.[39] Nonetheless, this borrowing has been undertaken at higher yields than in the past, reflecting continued investor caution and concern for debt sustainability.[40] The perceived high risk associated with lending to African economies is because the proceeds from new eurobond issuances are used to refinance old bonds or to finance ongoing fiscal spending. But the success of bond issuances by

African countries shows diverse innovative financing sources, lower refinancing risk, and strong investor demand.[41] Beyond easing access to international capital markets, African countries must strengthen fiscal discipline and foster a conducive environment for investment to develop domestic capital markets, especially local currency bond markets and local currency eurobonds.

Recent policy reforms have further contributed to better fiscal management—notably, reallocating resources away from inefficient spending, such as generalized fuel subsidies, towards high-impact sectors, such as infrastructure, human development, and climate adaptation. An estimated 30–40 per cent of infrastructure investment is wasted, but infrastructure spending inefficiency can be curbed by improving governance, enhancing transparency, and adopting digital tools such as e-procurement platforms and blockchain technology.[42] The (partial or full) removal of fuel subsidies in Angola, Guinea, Kenya, and Nigeria and the subsidy reform plans announced in Egypt and Senegal in 2025 have supported fiscal consolidation.[43] In addition, ongoing debt restructuring in Ethiopia, Ghana, and Zambia has reinforced a shift towards more prudent fiscal practices. Despite these advances, as well as measures to reform the international financial architecture, more needs to be done to ensure that debt restructuring through the Group of 20 Common Framework are timely, orderly, and effective.

Debt vulnerability remains elevated. Persistently high borrowing costs and currency depreciation pressure continue to weigh on debt dynamics, preventing a return to pre–Covid-19 pandemic debt ratios. In 2026, North Africa is projected to register the highest average debt-to-GDP ratio, at 73.9 per cent, followed by Southern Africa (70.0 per cent), Central Africa (49.4 per cent), West Africa (48.7 per cent), and East Africa (45.4 per cent) (see figure 1.7).

Frontier technologies and the associated technological innovation could play a major role in strengthening countries' fiscal frameworks and addressing debt vulnerability. Debt vulnerability across the region remains acute amid persistent uncertainty and exposure to a range of domestic and external shocks. These include subdued global growth prospects, volatile international financial conditions, declining ODA, weak domestic resource mobilization, poor public financial management, geopolitical conflicts, commodity price fluctuations, and climate-induced disasters—all of which could exacerbate debt burdens.

Across Africa, tax administrations are progressively deploying machine learning and artificial intelligence to strengthen revenue mobilization, improve compliance, and modernize taxpayer services.

Tight external financing conditions also elevate rollover risks, especially for countries with large debt maturities and limited refinancing options. Although debt restructuring is sometimes necessary, it remains a socially costly and administratively complex process.[44] The growing debt-servicing burden is increasingly constraining fiscal space for critical public investment and essential services, particularly in infrastructure, health, and education. As of March 2025, 7 African countries were in debt distress, and 11 others were at high risk of debt distress.[45]

The median interest-to-revenue ratio in Africa exceeded 12 per cent in 2024 and is projected to remain elevated, underscoring constrained access to concessional finance and a growing reliance on high-cost market-based borrowing.[46] With debt servicing absorbing up to 12 per cent of revenue in many countries—compared with 4 per cent in advanced economies—as well as limited revenue mobilization ability, declining ODA, and low growth prospects, the ability to finance critical spending on education, health, and infrastructure remains constrained. This is despite countries such as Benin, Côte d'Ivoire, Liberia, Nigeria, and Senegal expanding their tax base, reducing tax exemptions, and strengthening tax administration, especially through digitalization.[47]

Reshaping debt markets and debt management tools is essential to mitigate Africa's fiscal vulnerability to shocks. Since the bulk of Africa's debt is denominated in foreign currencies, debt-to-GDP ratios increase with the depreciation of exchange rates. This rather than weak economic fundamentals decreases African countries' fiscal space, pushing them deeper into the debt trap due to the burden of dollar-denominated liabilities.

To address this, African countries should expand the use of local currency financing, synthetic local currency bonds, and foreign exchange risk-hedging instruments to shield budgets from volatility and bring predictability to debt service. A recent milestone illustrates the way forward: in March 2025, Côte d'Ivoire issued Communauté financière africaine (CFA)–denominated bonds worth CFA 220 billion on international markets, the first such issuance by an African state.[48] Scaling such innovations across the continent would not only safeguard fiscal stability but also strengthen African capital markets, attract long-term domestic investors such as pension funds, and enhance sovereignty over development finance. Senegal's recent issuance of CFA 364 billion in local currency bonds (equivalent to $644 million) in July 2025 reflects growing investor confidence in local currency bond markets and should be replicated.[49]

In addition to issuing local currency bonds on international capital markets, deepen financial markets could allow African countries to tap into the excess liquidity observed in the financial systems of several countries. Local currency bond markets are critical in strengthening financial stability and supporting sustainable growth. They help cushion domestic economies against the impact of financial crises by providing local avenues for saving and investment. In fact, the recent crises, including those triggered by the Covid-19 pandemic, have underscored their importance: efficient local currency bond markets reduce exposure to currency risk, a frequent source of financial distress, thereby enhancing resilience. Beyond crisis mitigation, local currency bond markets are also central to developing broader capital markets to better transmit monetary policy. Together, these factors can lead to stronger, more sustainable long-term economic growth.

Given African economies' exposure to hard currency debt and frequent currency depreciation, synthetic local currency loans have proven an effective solution. In fact, synthetic local currency loans are structured so that borrowers repay their foreign currency–denominated debt in their local currency. This is achieved through derivatives, typically cross-currency swaps, which transfer the foreign exchange risk from the borrower to international investors or intermediaries.

Benin and Côte d'Ivoire showed dynamism in 2025 by reducing their debt burden and expanding fiscal space through innovative financing instruments such as debt swaps. Benin used its 2019 debt swap to free approximately 40 million euros for health and education needs,[50] and Côte d'Ivoire replaced expensive debt with cheaper financing using a debt-for-development swap operation to support the education sector, freeing up 330 million euros in 2025.[51]

HARNESSING DATA AND FRONTIER TECHNOLOGIES TO MOBILIZE DOMESTIC REVENUE

Across Africa, tax administrations are progressively deploying machine learning and artificial intelligence to strengthen revenue mobilization, improve compliance, and modernize taxpayer services. Kenya, Rwanda, and South Africa have embedded artificial intelligence in their systems to curb fraud and enhance tax compliance.

In 2013, the Kenya Revenue Authority launched iTax and rolled out eTIMS with artificial intelligence—based features to detect anomalies in filing patterns, automate value added tax refund verification, and flag suspicious transactions. The artificial intelligence–assisted approach supported the recovery of 62 billion Kenyan shillings in previously undeclared taxes in 2021/2022 through targeted audits and fraud prevention. Artificial intelligence–enabled chatbots cut taxpayer-query response times by more than 50 per cent, and integration of mobile money data with artificial intelligence–driven detection reduced value added tax refund fraud by nearly 30 per cent between 2019 and 2021.[52] However, sustained and specialized capacity is required to maintain models and mitigate algorithmic bias. While gains are notable among large taxpayers, gaps remain for micro and small businesses—underscoring the need to complement artificial intelligence with simplified regimes and taxpayer education.

The Rwanda Revenue Authority has used its Electronic Billing Machines to introduce machine learning algorithms to enhance risk-based compliance and short-term revenue forecasting. This has led to a 5–8 per cent increase in compliance among high-risk taxpayers, a 12 per cent reduction in short-term forecasting errors, and time savings in audit prioritization.[53]

In 2016, the South African Revenue Service integrated machine learning algorithms into its tax compliance status system as a step towards artificial intelligence–enabled tax governance.[54] Advanced algorithms in the Tax Compliance Status system detect fraudulent filings, enhance audit targeting, and reconcile taxpayer declarations with third-party data. Reported impacts include 293.7 billion rands in compliance revenue in 2022/2023 (a 26.7 per cent year-on-year increase), with 101 billion rands attributed to compliance and risk management interventions such as fraud prevention, audit targeting, and storage compliance.[55] Automation has also improved services, such as faster processing of returns, and by mid-2024, 45 billion rands in impermissible refunds were prevented using artificial intelligence–enabled verification.[56]

EXPECTED DISINFLATION AT THE SUBREGIONAL LEVEL DESPITE HIGH INFLATION IN SOME COUNTRIES

The regional inflation average rate is projected to decline from an estimated 11.3 per cent in 2025 to 9.1 per cent in 2026 and 8.2 per cent in 2027, driven by declining food prices and by declining global energy prices in oil-importing countries (figure 1.8). The number of countries with double-digit inflation is projected to decline from 15 in 2024 to 10 in 2026.[57] But inflation will remain high in some countries because risks remain skewed to the upside, underpinned by possible commodity prices, exchange rate volatility, and adverse weather conditions.

The regional inflation average rate is projected to decline from an estimated 11.3 per cent in 2025 to 9.1 per cent in 2026 and 8.2 per cent in 2027.

Figure 1.8 Annual consumer inflation in Africa, by subregion, 2019–2027

a. Estimated. b. Projected.
Source: United Nations 2026.

Disinflation is expected in all subregions, driven by declining food inflation and more stable currencies. In Southern Africa, average inflation is projected to rise from an estimated 10.7 per cent in 2025 to 11.1 per cent in 2026 before edging down to 9.0 per cent in 2027.[58] Monetary and currency stability in Zimbabwe and containment of inflation in Common Monetary Area countries[59] will also contribute to disinflation.[60] Inflation in Malawi remains in double digits as the country faces rising inflationary pressure underpinned by higher maize prices, currency weakness, rapid money supply growth, and higher electricity tariffs.[61] Easing price pressure in West Africa, from an estimated 17.1 per cent in 2025 to 9.6 per cent in 2027, reflect the rebasing of the consumer price index to 2024, moderating fuel prices, and a stabilizing exchange rate in the subregion's largest economy, Nigeria, as well as currency stability and lower commodity prices in Ghana.[62]

Similarly, inflation is projected to decline in East Africa from an estimated 10.2 per cent in 2025 to 8.4 per cent in 2026 before reaching 7.6 per cent in 2027, due to lower inflation in Uganda resulting from lower commodity prices and a stable currency[63] and to lower prices in Rwanda resulting from improved agricultural production and lagged effects of tight monetary policy.[64] In North Africa, average inflation is projected to decelerate from 7.6 per cent in 2025 to 6.3 per cent in 2026 and to increase to 7.2 per cent in 2027. But inflationary pressure remains elevated due to subsidy cuts and a weaker exchange rate in Egypt, alongside wage increases and central bank fiscal deficit financing.[65] Central Africa is projected to register the lowest average inflation rate at an estimated 2.8 per cent in 2025, 2.9 per cent in 2026, and 2.8 per cent in 2027, reflecting the hard peg currency regime, which is associated with inflation discipline and confidence.[66] Inflation in the Central African Economic and Monetary Community is projected to return to the regional 3.0 per cent convergence criterion by 2026, supported by lagged effects of tight monetary policy and declining global food prices.[67]

In line with the variable inflation across countries, there has been divergence in monetary policy responses, as countries with high inflation rates such Ghana and Zambia tightened monetary policy in early 2025 to curb inflationary pressure and support economic growth. By the end of 2025, Ethiopia, Nigeria, Uganda, and Zimbabwe had paused the hiking cycle, while Egypt and Kenya had reduced policy rates, reflecting anchored and stable inflation expectations.[68] Monetary policy stance will remain differentiated across countries because of inflation, policy uncertainty, and currency movements. Decisions by the US Federal Reserve System may not affect monetary policy responses in Africa, as central banks are more focused on maintaining domestic price stability and supporting exchange rates.[69]

Exchange rate dynamics remain one of the main risks to inflation estimates and are likely to be influenced by US trade policy uncertainty.

CURRENCIES STRENGTHENED AGAINST THE US DOLLAR

Exchange rate dynamics remain one of the main risks to inflation estimates and are likely to be influenced by US trade policy uncertainty. The US dollar depreciated in the first half of 2025, underpinned by the imposition of tariffs and subsequent policy and economic uncertainties. This bodes well for Africa, with most currencies stabilizing in 2025.[70] Exchange rate appreciation could be associated with lower inflationary pressure or a smaller effect of external price increases. The pass-through of global shocks, including currency volatility, to domestic prices depends on the exchange rate regime, policy credibility, trade structure, international reserves, and export earnings. While strengthening currencies may reduce the debt service burden through lower borrowing costs, they constrain export competitiveness in many economies.[71]

The Kenyan shilling remained stable at around 129.30 shillings per US dollar in 2025, supported by higher export earnings and remittances, as well as monetary policy measures. The currency will remain stable in the near term, underpinned by the continued coordination of fiscal and monetary policies and modernization of the monetary policy framework and operations.[72] The South African rand appreciated by 7.9 per cent, from 18.18 rands per US dollar in December 2024 to 16.86 in December 2025, in response to global factors.

The rand strengthened due to the weakness of the US dollar as a result of shifting inflation expectations in the United States and mounting doubts about the health of the US economy, combined with uncertainty about US international trade policies.[73] The Nigerian naira strengthened by 6.6 per cent, from 1,554.93 naira per US dollar in December 2024 to 1,451.80 in December 2025. This relative stability reflects the impact of policy measures by the Central Bank of Nigeria, including the introduction of the Electronic Foreign Exchange Market System, which has enhanced transparency, improved liquidity, and supported more effective price discovery in the foreign exchange market. It also reflects the $200 million foreign exchange injection to support investor confidence and maintain economic stability.[74] The Egyptian pound appreciated by 5.9 per cent, to 47.57 pounds per US dollar, bolstered by a more flexible exchange rate regime and an IMF programme.[75] The CFA franc also remained stable, appreciating by 10.5 per cent to 560.23 CFA francs per US dollar, bolstered by its peg to the euro.[76]

MONETARY AUTHORITIES ARE EMBRACING DIGITAL ASSETS AND TECHNOLOGY

Technological innovation to enhance financial system efficiency and transmit monetary policy is advancing on the continent, as evidenced by the adoption of digital currencies, eMoney, and digital payment systems. Financial technology is being used for information dissemination, market integration, new financial products, and increased leverage. But these advancements may have implications for monetary policy, economic, and financial stability.

Recent financial innovations such as central bank digital currencies and digital payment systems have shaped monetary policy effectiveness in some countries. Central bank digital currencies are a sovereign digital form of currency, considered legal tender that exists solely in digital form issued by central banks.[77] They offer secure, low-cost digital accounts accessible to a wide population, including the unbanked, and thus boost the proportion of the economy directly influenced by central bank decisions. This broader reach allows policy rate changes to have a more immediate and inclusive impact on consumption, savings, and investment

Technological innovation to enhance financial system efficiency and transmit monetary policy is advancing on the continent, as evidenced by the adoption of digital currencies, eMoney, and digital payment systems.

behaviour. Ghana (which is piloting e-Cedi), Nigeria (with eNaira), and South Africa (which is piloting a wholesale central bank digital currency) are at the forefront of this digital shift, using central bank digital currencies not only to boost financial inclusion but also to strengthen the effectiveness of monetary policy. The launch of the first central bank digital currency, the eNaira, by the Central Bank of Nigeria in 2021 in Africa, represents a major step forward in digital financial innovation on the continent and provides a foundation for future improvements in Nigeria's monetary and financial landscape.[78] But there are implications for monetary policy, as central bank digital currencies are likely to change control over money supply and policy transmission mechanisms (interest rates, credit, and money supply). Central bank digital currencies may also affect financial stability by introducing vulnerabilities related to cybersecurity, capital flows, and the structure of banking systems.[79]

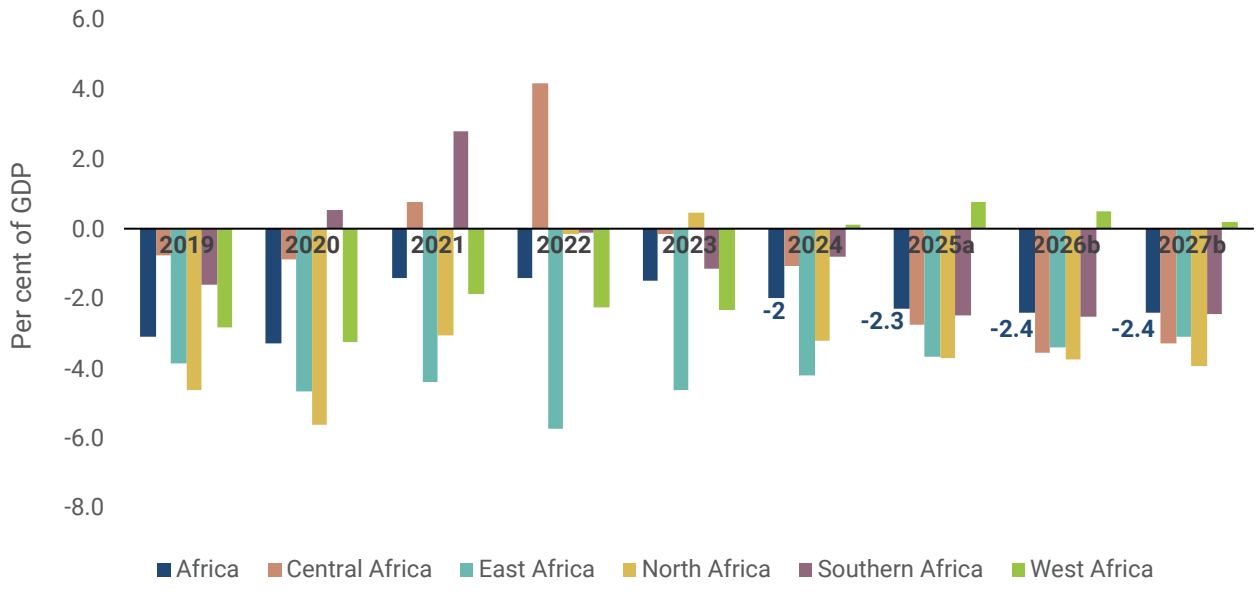
The launch of the Pan-African Payment and Settlement System by the African Union Commission, in collaboration with member states, is designed to facilitate real-time cross-border payments and settlements across Africa. It will play a transformative role in monetary policy by providing central banks with accurate and timely data to inform policy decisions, enhancing liquidity management, and improving financial inclusion and the effectiveness of monetary transmission mechanisms. Digital payment systems, including such notable innovations as M-Pesa in Kenya, real-time gross settlement systems, mobile telephone network mobile money, PayPal, automated teller machines, point of sale terminals, digital mobile lending applications, and agency banking, also continue to facilitate access to core financial services—for example, mobile transfers, mobile payments, and mobile banking (chapter 5).

EXTERNAL SECTOR AND CURRENT ACCOUNT DEVELOPMENTS

Africa's average current account deficit is projected to deteriorate from 2.0 per cent of GDP in 2024 to an estimated 2.3 per cent in 2025 and 2.4 per cent in 2026–2027.

Africa's average current account deficit is projected to deteriorate from 2.0 per cent of GDP in 2024 to an estimated 2.3 per cent in 2025 and 2.4 per cent in 2026–2027 (figure 1.9). The current account will remain in deficit in the short to medium term, underpinned by the widening trade deficit, which is driven by an expected decline in international commodity prices. Energy prices are projected to decline by an estimated 12.4 per cent in 2025 and 10.2 per cent in 2026, moderated by an increase in metal and mineral prices of an estimated 2.9 per cent in 2025 and 0.3 per cent in 2026.[80] The decline in commodity prices will mostly affect mineral-rich countries, such that oil-rich countries will transition to a current account deficit of 0.7 per cent of GDP and mineral-rich countries will record a deficit of 3.2 per cent in 2026.[81] But remittances are projected to maintain their upward trend due to the stable labour markets in some high-income migrant-hosting countries.[82] Half of African countries will see a decline in reserves coverage in 2025 compared with 2024. More than half of countries will record more than 3 months of imports, but Burundi, Djibouti, Togo, and Zimbabwe will record less than 1 month of imports.

Figure 1.9 Current account balance in Africa, by subregion, 2019–2027



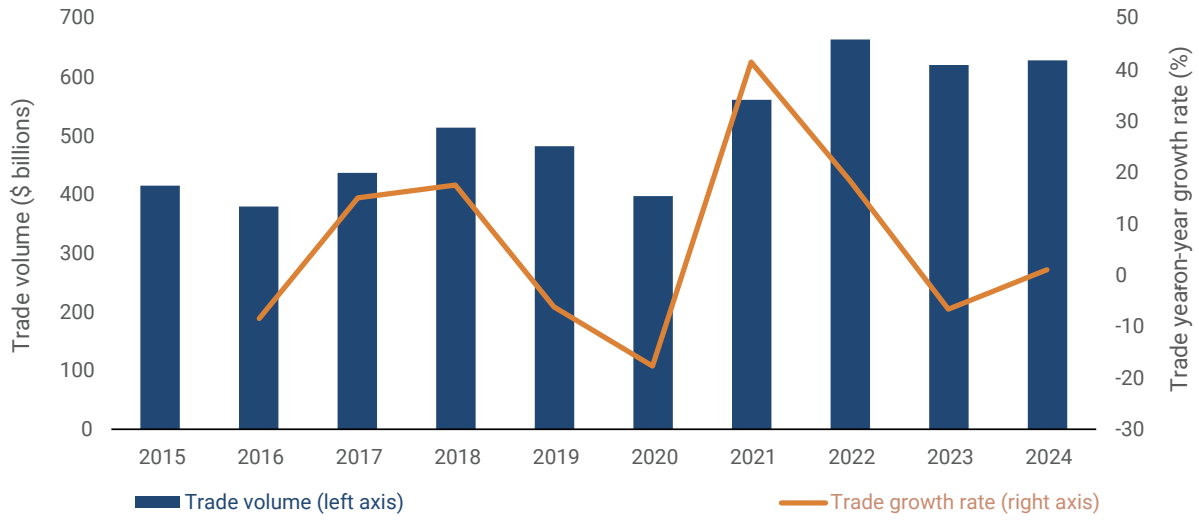
a. Estimated. b. Projected.
Source: IMF 2025a.

TRADE REMAINS VULNERABLE TO GLOBAL SHOCKS, DESPITE SIGNS OF RECOVERY

Africa's trade has experienced notable fluctuations over the past decade. Trade volumes grew steadily from 2015 to 2018 but declined 18 per cent through 2020 due to the Covid-19 pandemic. In 2021, trade rebounded considerably, increasing by 41 per cent (figure 1.10). This recovery was driven by the easing of pandemic-related restrictions and the mitigation of supply chain disruptions. However, from 2021 to 2023, trade declined again by 7 per cent, influenced by global shocks, including the war in Ukraine, climate-related effects, and other external pressures, before recovering in 2024.

In 2024, Africa's total exports reached $630 billion, while intra-Africa exports hit a record high of $106 billion.

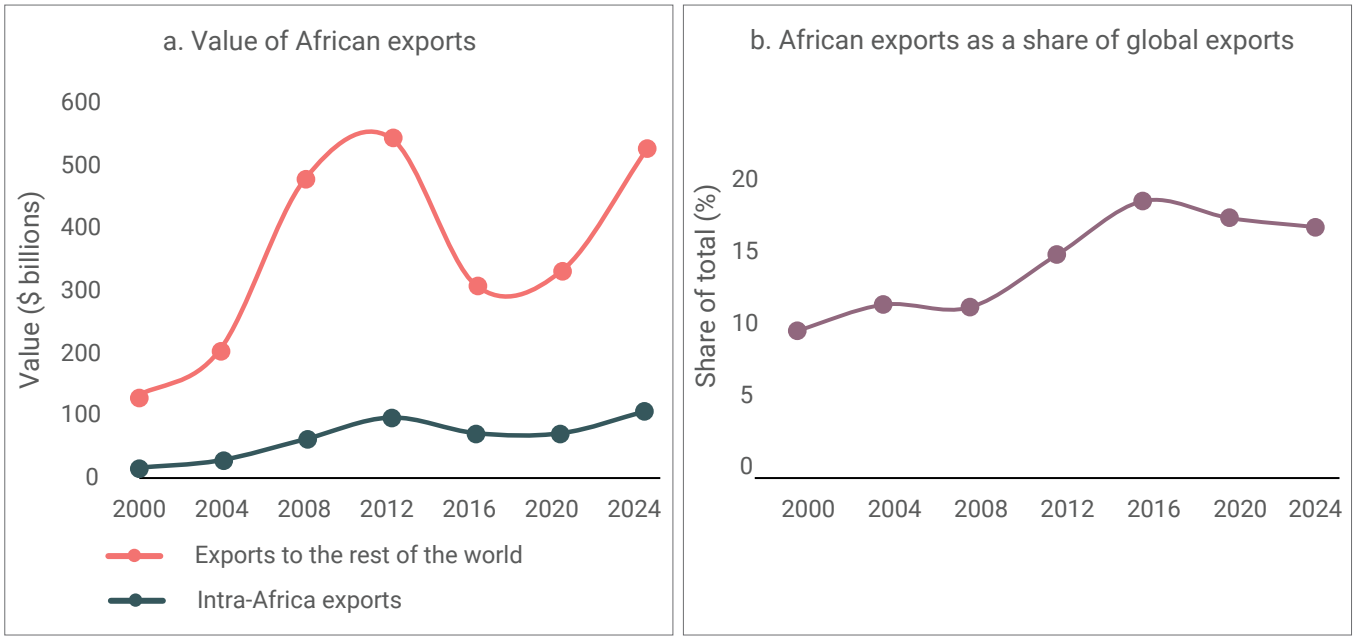
Figure 1.10 Total African trade and year-on-year growth rate, 2015–2024



Source: ECA calculations based on UNCTAD (2025c).

Despite these fluctuations, the value of Africa's exports to the rest of the world increased from 2019 to 2024. In 2024, Africa's total exports reached $630 billion, while intra-Africa exports hit a record high of $106 billion (figure 1.11a). Although intra-Africa trade rose in value terms, its share in total global exports remained stagnant at around 17 per cent in 2024 (figure 1.11b). This underscores the urgency of accelerating implementation of the African Continental Free Trade Area (AfCFTA) to unlock the full potential of continental integration. The AfCFTA has the potential to transform African economies by diversifying export sources and growth and enhancing regional value chains, thereby boosting participation in global value chains.

Figure 1.11 Global and intra-Africa exports, 2000–2024

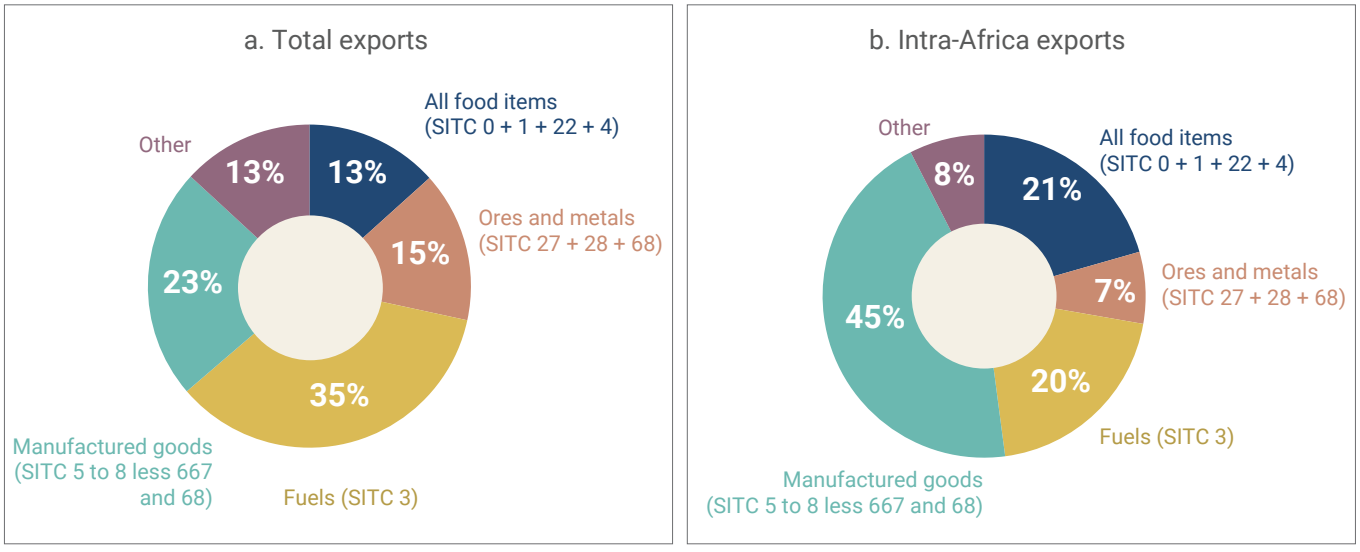


Source: UNCTAD (2025c), UNCTADstat database.

Despite continued efforts to industrialize, Africa's total exports remain heavily concentrated in primary commodities. On average, fuel constituted 35 per cent of the continent's total exports between 2020 and 2024, while ores and metals made up 15 per cent (figure 1.12a). Combined, these two sectors accounted for half of Africa's total exports to the global market. Manufactured goods, by comparison, represented only 23 per cent of exports. The heavy reliance on commodity exports leaves Africa at the lower end of value chains and dependent on other regions for manufactured and finished goods.

Conversely, manufactured products make up 45 per cent of total intra-Africa trade, followed by food items at 21 per cent (figure 1.12b). Both the manufacturing and food sectors are vital for the continent, as they have been identified as key drivers with strong potential to enhance intra-Africa trade under the AfCFTA framework.

Figure 1.12 Composition of Africa's exports, by main sector, average over 2020–24



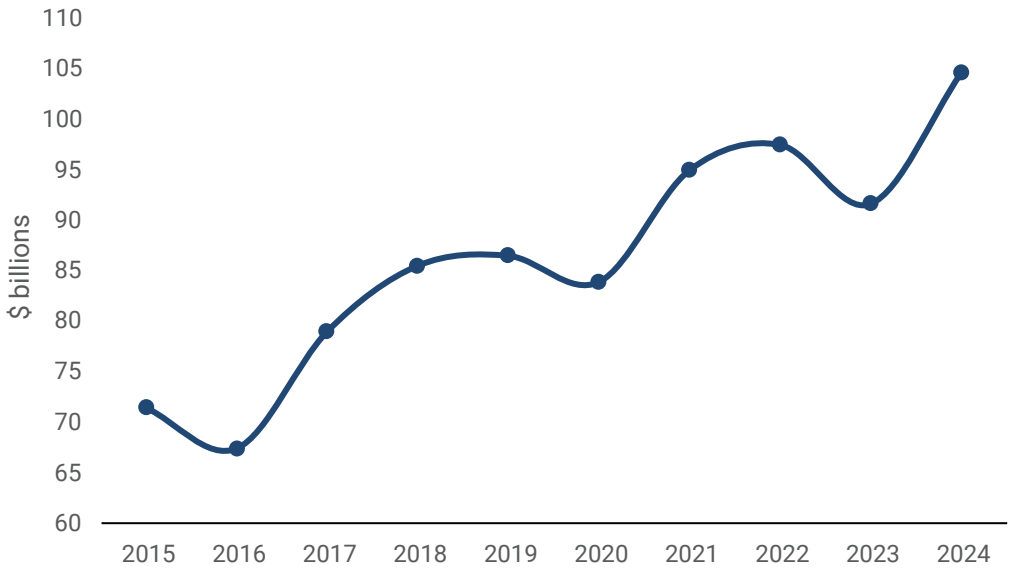
Source: UNCTAD (2025c), UNCTADstat database.

REMITTANCE FLOWS ARE BOLSTERED BY STRONG LABOUR MARKETS IN ADVANCED ECONOMIES

Remittance inflows to Africa continue to boost the current account, with an average growth of 10.1 per cent from 2021 to 2024, to $104.6 billion, supported by strong economic performance in migrant-hosting economies and more stable currencies.

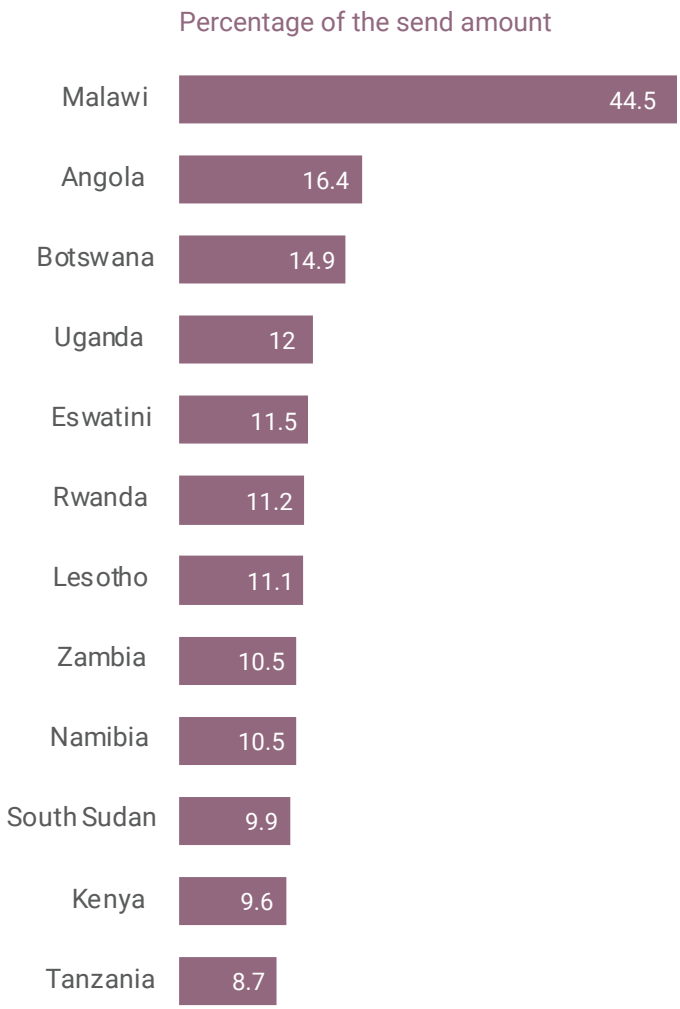
Remittance inflows to Africa continue to boost the current account, with an average growth of 10.1 per cent from 2021 to 2024, to $104.6 billion, supported by strong economic performance in migrant-hosting economies and more stable currencies (figure 1.13). The largest recipients in 2024 were Egypt ($29.6 billion), Nigeria ($21.3 billion), and Morocco ($12.5 billion). Even though remittances remain the lifeline for many Africans, transfer costs to Africa remain excessively high compared with those to other regions. The average cost of sending $200 to Africa was 8.22 per cent, compared with the global average of 6.5 per cent in November 2024. During the first quarter of 2025, sending remittances through banking channels cost an average of 21 per cent, and sending through non-banking channels cost 6.3 per cent.[83] Malawi recorded the highest cost at 44.5 per cent followed by Angola at 16.4 per cent and Botswana at 14.9 per cent (figure 1.14). These high costs make it difficult to leverage remittances as a source of development financing.

Figure 1.13 Total remittances inflows into Africa, 2015–2024



Source: Remitscope 2025.

Figure 1.14 Average transfer cost for remittances (bank and non-bank) for selected African countries, January–March 2025



Source: Remitscope 2025.

During the first quarter of 2025, sending remittances through banking channels cost an average of 21 per cent, and sending through non-banking channels cost 6.3 per cent of the amount sent.

In terms of current account transfers, food aid, commodity vouchers, and cash transfers increased in 2024 due to adverse weather conditions, continuous development challenges, high food prices, and acute food insecurity in the continent. The World Food Programme spent approximately $147 million on food and cash assistance in Southern Africa in response to a drought that led to livestock losses and crop failure. Food insecurity further increased in 2025 in the Democratic Republic of the Congo (which required $433 million in food aid, cash transfers, and climate resilience), Ethiopia ($150 million), Somalia ($266 million), and South Sudan ($274 million). The worsening food insecurity is attributed to ongoing conflicts, displacements, and climate and economic shocks.[84] Both remittances and current transfers will offset the deficit in the trade account.

FOREIGN DIRECT INVESTMENT MOMENTUM UNCERTAIN AMID THE GLOBAL ECONOMIC SLOWDOWN

Global FDI flows declined by 11 per cent in 2024, marking the second consecutive year of contraction.[85] This figure excludes artificially inflated flows routed through conduit economies (jurisdictions often used for tax or regulatory purposes rather than real investment activity).

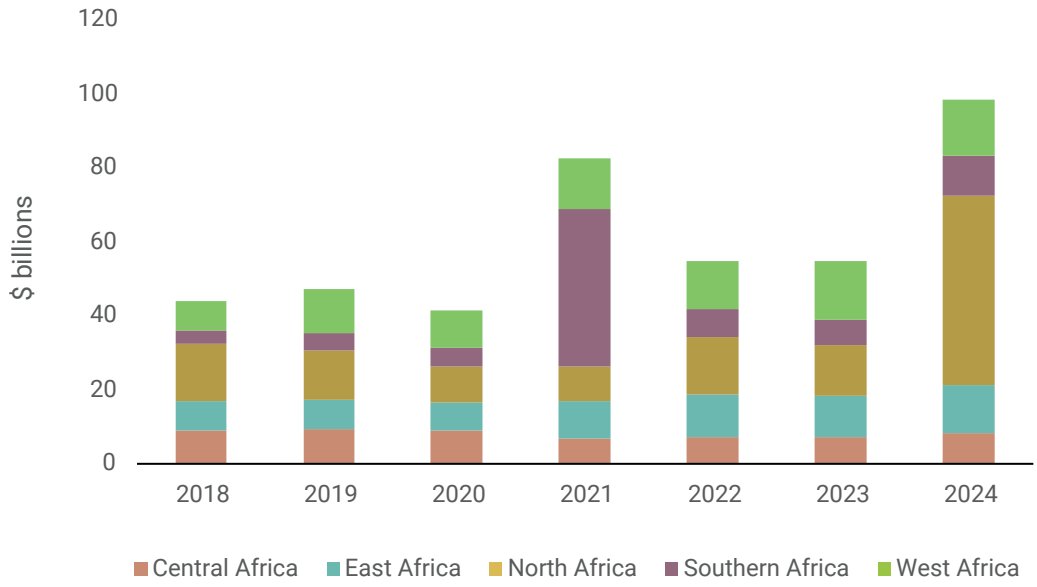
The global investment landscape remains uneven and uncertain. Developed economies saw divergent trends: sharp declines in Europe were offset by gains in North America, while developing country flows were highly concentrated, with just 10 countries capturing three-quarters of the total. At the sector level, investment in the digital economy surged, doubling in value and reshaping the portfolios of multinational enterprises, while Sustainable Development Goal–related investment plunged by up to a third across key sectors.

Amid this global downturn, Africa emerged as a notable outlier, showing renewed investor momentum and a sharp upswing in FDI inflows. Africa saw a remarkable 75 per cent surge in FDI inflows, from $55 billion in 2023 to $97 billion in 2024, accounting for 6 per cent of global FDI. The spike was driven by the $35 billion Ras El-Hekma megaproject in Egypt,[86] but even without that, Africa posted a solid 12 per cent gain from 2023. Beyond Egypt, Morocco recorded a 55 per cent increase, buoyed by new investment in green ammonia and synthetic fuel production.

North Africa recorded the highest FDI inflows, worth $51 billion in 2024, up from $16 billion in 2023.

Tunisia also saw a 21 per cent rise in FDI, supported by a $6 billion greenfield renewable energy project by Total Energies (France). Thus, North Africa recorded the highest FDI inflows, worth $51 billion in 2024, up from $16 billion in 2023 (figure 1.15).

Figure 1.15 Foreign direct investment flows, by subregion, 2018–2024



Note: The surge in 2021 was influenced by a single intrafirm transaction in South Africa related to a major corporate reconfiguration through a merger and acquistion.

Source: UNCTAD 2025a.

Breaking down inflows by investment type reveals diverging trends. In 2024, the value of international project finance deals—a vital channel for funding large-scale infrastructure projects—rose by 15 per cent in Africa, driven by primary energy and transport investment, particularly in Egypt. In contrast, greenfield investment—critical for new capital formation, technology transfer, and structural transformation—fell sharply, with the total value dropping by 37 per cent to $113 billion from $178 billion in 2023.[87] Meanwhile, cross-border mergers and acquisitions turned negative, led by Exxon Mobil's $1.1 billion divestment of its Nigerian oil assets to Seplat Energy, a Nigerian energy provider. While this may reflect growing investor caution and possible decarbonization objectives, it might also signal a shift towards greater domestic ownership of strategic sectors.

Energy, extractives, and construction remain the leading drivers of greenfield project activity in Africa, while the digital economy is emerging as a fast-growing sector. In 2024, energy overall accounted for more than 20 per cent of total greenfield investment value. Extractives contributed 13 per cent, with the Democratic Republic of the Congo, Namibia, and Zambia continuing to attract investment in mining and exploration. Yet tighter financing conditions and growing environmental scrutiny have prompted

a more selective approach by sponsors and lenders. Long-term demand for critical minerals continues to sustain strategic interest in Africa's extractive sector. Going forward, robust public policy support to de-risk investment and promote local and regional value addition will be essential to overcome stagnation in manufacturing and drive structural transformation anchored in resource-based sectors. Construction made up nearly 10 per cent of total investment. While project numbers declined sharply, total investment surged by nearly 50 per cent, pointing to a clear shift towards fewer but larger capital-intensive infrastructure projects. Meanwhile, the digital economy—still modest at about 6 per cent of total greenfield investment by value—has emerged as one of the fastest growing sectors, with project values rising by more than 75 per cent and project numbers up nearly 30 per cent from 2019 to 2024.

Traditional investors remain the largest holders of FDI stock in Africa, led by the Netherlands ($70 billion), the United Kingdom ($58 billion), the United States ($56 billion), France ($53 billion), and China ($42 billion), as of 2023.[88] The substantial stock attributed to the Netherlands partly reflects its role as a financial conduit jurisdiction, with some investment ultimately owned by entities based elsewhere, particularly in the United States. The FDI stock owned by the United States rose sharply between 2019 and 2023, fuelled by new investment across sectors, including digital infrastructure, as well as expansions, asset revaluations, and other factors. China's footprint is increasingly diversified beyond extractives, with rising investment in building materials, food processing, pharmaceuticals, and motorcycle manufacturing. Notably, a third of Belt and Road Initiative projects in Africa focus on social infrastructure—health, education, water, and sanitation—with growing attention to renewable energy. South Africa, ranking sixth with $32 billion in FDI stock owned across other African countries, is asserting its role as a major African capital exporter.[89]

Even so, early 2025 signalled a cooling of momentum, as preliminary data for the first half of the year shows global FDI down by 3 per cent and inflows to Africa down by 42 per cent. That sharp drop is shaped mainly by the base effect of Egypt's extraordinary 2024 megaproject; excluding it moderates the decline to 8 per cent. Several pressures emerged

...early 2025 signalled a cooling of momentum, as preliminary data for the first half of the year shows global FDI down by 3 per cent and inflows to Africa down by 42 per cent.

during this period: investment in the primary sector fell by 76 per cent, driven by continued low energy prices; greenfield manufacturing slowed, particularly in countries affected by US tariff hikes, notably South Africa, as investors pulled back from supply chain–intensive sectors; and international project finance in the Least Developed Countries dropped by 85 per cent, constrained by high interest rates and tighter capital availability. But signs of resilience remain: renewable energy project finance expanded, led by two major battery storage projects—a 10 MW facility in Somalia and a 15 MW system in Niger, both backed by Canadian sponsors.[90] This softening comes after exceptionally high FDI flows in 2024, and since these data reflect only the first half of 2025, it remains a trend to monitor rather than a settled reversal.

DIGITAL TECHNOLOGIES ARE KEY TO CROSS-BORDER TRADE AND REGIONAL INTEGRATION

Advances in digital technologies in Africa are reshaping industries and bringing transformative innovations in trade and other cross-border transactions. The AfCFTA provides a game-changing framework to increase trade-led growth, unlock regional value chains, boost competitiveness, and ensure that Africa transitions from being a supplier of raw materials to a producer of high-value goods and services. Digital infrastructure and platforms such as the Pan-African Payment and Settlement System support the AfCFTA's objectives by enhancing intra-Africa trade. The system allows transactions in 42 African currencies by connecting central and commercial banks, payment service providers, and financial intermediaries. It reduces transaction costs and time, promotes transparency, and formalizes informal trade flows.[91]

The penetration of mobile technology in Africa is increasing consistently and has revolutionized remittances by offering cost-effective and instant transfers. Globally, mobile money growth remained highest in Africa, with a transaction value of $1.1 trillion (66 per cent of the global share). African mobile money providers have partnered with prominent payment providers to promote the use of virtual and physical cards across borders and to advance international remittances. In 2024, MTN MoMo partnered with Mastercard in 13 African markets, Safaricom and M-Pesa partnered with Mastercard in Kenya, and Orange Money partnered with Mastercard for the use of the virtual and physical cards in Cameroon, Central African Republic, Guinea-Bissau, Liberia, Mali, Senegal, and Sierra Leone.[92] MTN MoMo operates in 16 African countries providing low-cost payments in the form of loans, remittances, savings, and insurance. Remittances through the system rose by 43.3 per cent to $4.4 billion in 2024 (chapter 5).[93] Global transactions through Kanya's M-Pesa were valued at 418 billion shillings in 2023, up 5.6 per cent from 2022, with a 3 per cent reduction in cost of remittances over the same period.[94]

The penetration of mobile technology in Africa is increasing consistently and has revolutionized remittances by offering cost-effective and instant transfers. Globally, mobile money growth remained highest in Africa, with a transaction value of $1.1 trillion (66 per cent of the global share).

RECENT SOCIAL DEVELOPMENTS

THE PACE OF POVERTY REDUCTION HAS VARIED ACROSS COUNTRIES

While poverty in its many forms is a persistent development challenge across many African countries, there are several success stories of poverty reduction. The progress made can serve as encouragement for countries that have seen poverty rising. Those countries require urgent action to kick-start and accelerate comprehensive poverty reduction initiatives.

MULTIDIMENSIONAL POVERTY

Poverty is a multidimensional phenomenon that goes beyond just monetary aspects. Measures of multidimensional poverty such as the global Multidimensional Poverty Index, highlight the multiple and simultaneous deprivations that people face. The global Multidimensional Poverty Index is widely used for regional comparisons and includes 10 indicators that span the equally weighted dimensions of health, education, and living standards. Three countries with data for 2019 or later have a multidimensionally poverty headcount ratio of 80 per cent or higher: Central African Republic, Chad, and Niger (table 1.2).[95] In contrast, in several African countries, the share of multidimensionally poor people is less than 10 per cent, underscoring the range in poverty rates on the continent. Multidimensional poverty also varies widely within countries. In Nigeria, the share of multidimensionally poor people in Lagos was 1 per cent, compared with 75 per cent in Bauchi.[96]

Table 1.2. Highest and lowest headcount ratios of multidimensional poverty in African countries with surveys for 2019 or later (per cent)

Country (survey year)	Headcount ratio	Country (survey year)	Headcount ratio
Chad (2019)	84.2	Gabon (2019/2021)	8.6
Central African Republic (2018/2019)	80.4	Eswatini (2021/2022)	7.9
Niger (2021)	79.9	Algeria (2018/2019)	1.4
Ethiopia (2019)	68.7	Tunisia (2023)	1.0
Madagascar (2021)	68.4	Seychelles (2019)	0.9

Source: UNDP and OPHI 2025.

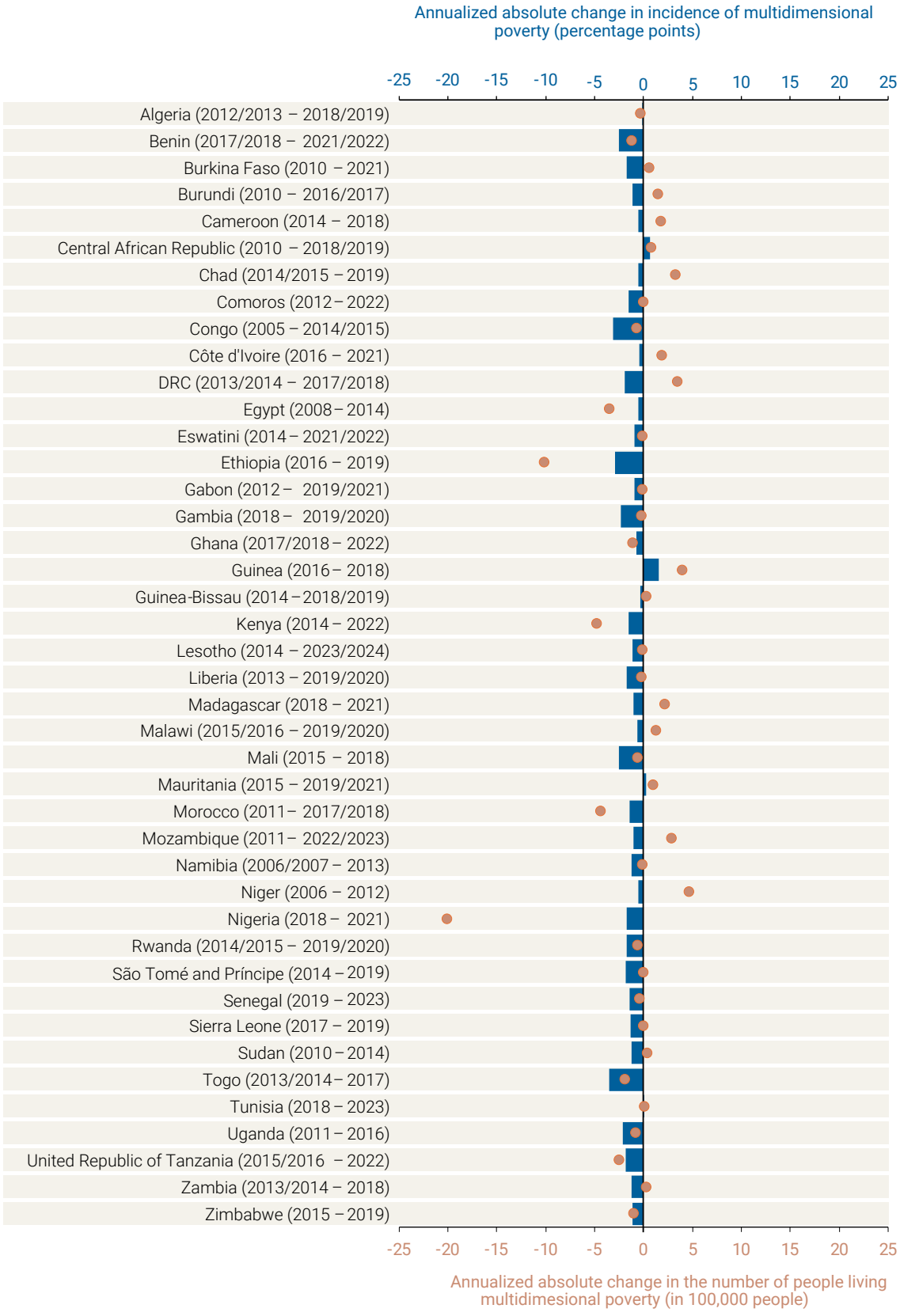
Trends in multidimensional poverty

In the two most recent surveys, declines in the incidence of multidimensional poverty across African countries have occurred alongside increases in the number of people living in multidimensional poverty. This has especially common in the Least Developed Countries, particularly Chad, Côte d'Ivoire, the Democratic Republic of the Congo, Madagascar, Mozambique, and Niger (figure 1.16). In these countries, population growth, among other factors, led to an increase in the number of poor people living in multidimensional poverty, as progress in poverty reduction was limited. But in several countries, both the incidence of multidimensional poverty and the number of multidimensionally poor people have declined. Kenya, Nigeria, Morocco, and Togo showed the most progress in this regard.

Trends in extreme monetary poverty

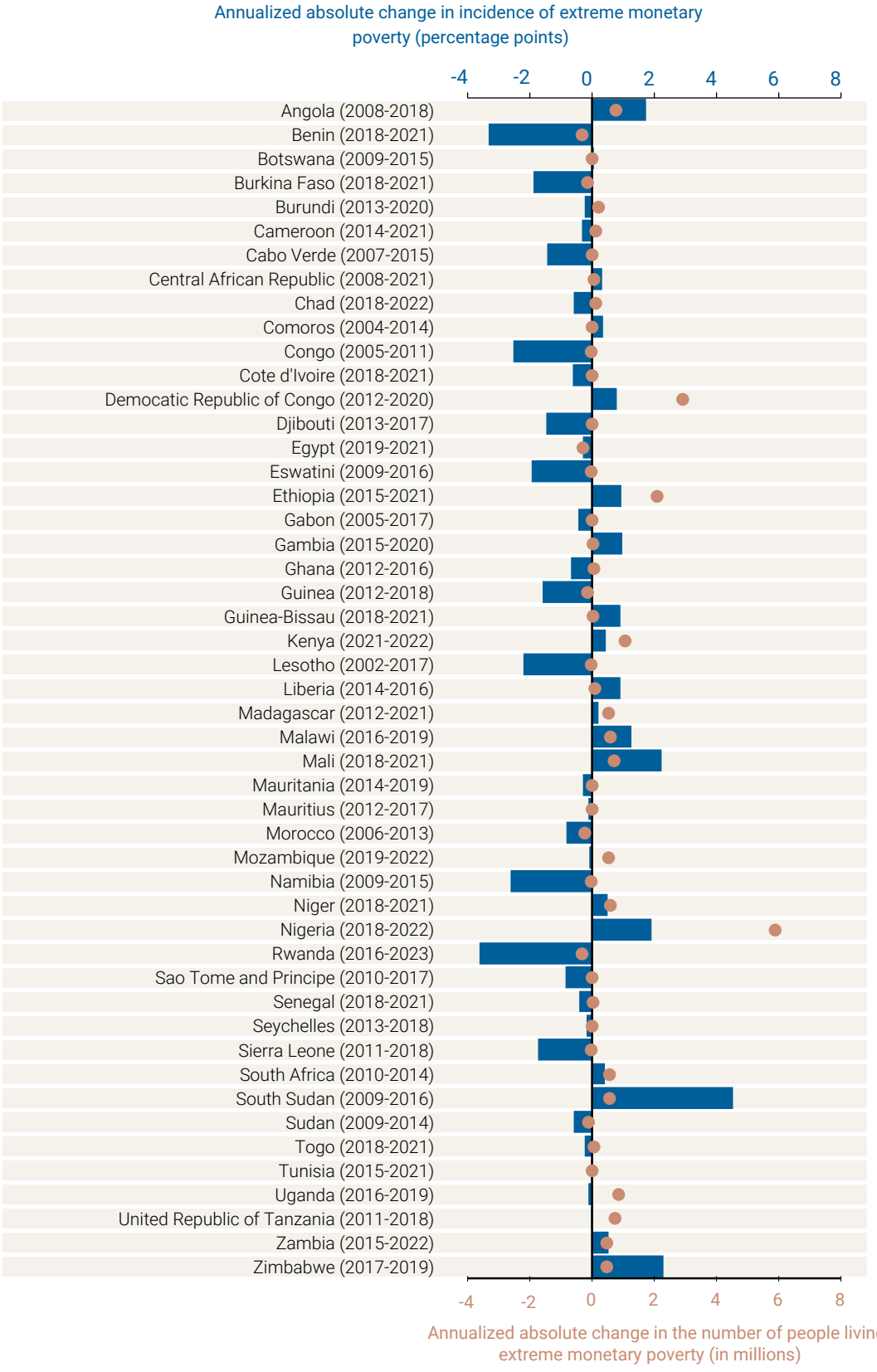
Extreme monetary poverty, as measured by the World Bank's international poverty line of $3 a day, has declined in several countries (figure 1.17).[97] Benin, Congo, Namibia, and Rwanda recorded steep declines in the incidence of extreme monetary poverty in their two most recent surveys. In contrast, the incidence and number of people living in extreme monetary poverty has increased in several countries, including Angola, Malawi, Mali, Nigeria, and South Sudan.

Figure 1.16. Trends in the incidence of multidimensional poverty and the number of people living in multidimensional poverty in Africa, various years



Source: ECA using data from Alkire et al. (2025).

Figure 1.17. Incidence of extreme monetary poverty and the number of people living in extreme monetary poverty in Africa, various years



- Annualized absolute change in the incidence of extreme monetary poverty ($3.00 per day)
- Annualized absolute change in the number of people living in extreme monetary poverty ($3.00 per day)

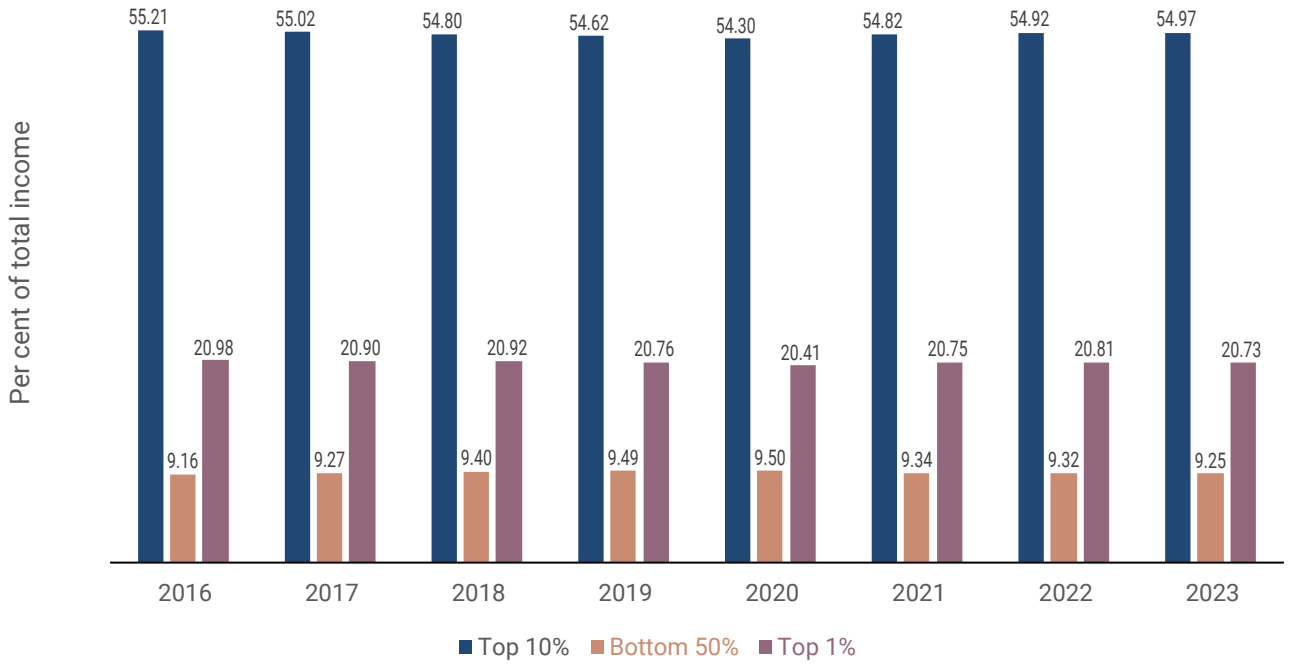
Source: ECA using data from World Bank (2025i).

INCOME INEQUALITY REMAINS PERVASIVE

Most African countries have experienced high income inequality recently. More than half of Africa's income is earned by the top 10 per cent of the income distribution, while the bottom 50 per cent earns less than a tenth. Within the top decile, the top 1 per cent alone accounts for around a fifth of total income, suggesting a strong concentration of income at the very top. This situation has remained largely unchanged since 2016 (figure 1.18).

Most African countries have experienced high income inequality recently and this situation has remained largely unchanged since 2016.

Figure 1.18. Income inequality in Africa, 2016–2023



Source: ECA based on data from World Inequality Lab (2025).

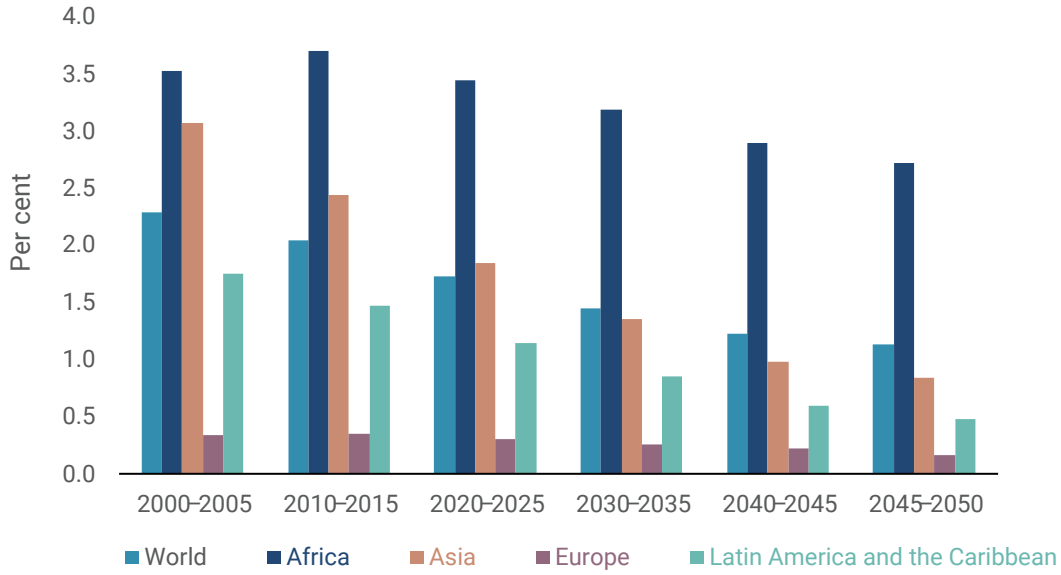
Inequality is highest in Southern Africa, home to the 15 most unequal countries on the continent, including Angola, Botswana, Eswatini, Mozambique, Namibia, South Africa, Zambia, and Zimbabwe. Countries in North Africa—including Algeria, Egypt, and to some extent, Tunisia—have less inequality. These countries also have lower rates of multidimensional and monetary poverty.

AFRICA REMAINS THE FASTEST URBANIZING REGION GLOBALLY

Since 1990, Africa has experienced unprecedented urban growth—a trend that is projected to continue, making it the fastest urbanizing region globally. The share of the population living in cities rose from 31 per cent in 1990 to 54 per cent in 2020. As of 2025, Africa's cities continue to expand at an extraordinary pace, with the continent's urban population increasing at more than 3.5 per cent a year (figure 1.19). This growth is driven by the high fertility rate, 4.6 children per woman (the highest globally), compared with the global average of 2.4.[98] The relationship between fertility and urbanization is particularly strong in countries with higher-than-average urban population growth. In 2020, the average fertility rate was 4.1 children per woman across the continent, but it rose to 5.8 in countries where urban population growth exceeded 3.5 per cent a year.[99] In extreme cases—such as Chad, the Democratic Republic of the Congo, Mali, and Niger—urban population growth surpassed

4 per cent a year, with fertility rates above 6 children per woman.[100] Driven by the search for employment, access to services, or displacement from conflict and other shocks, rural-to-urban migration adds further to pressure to urban population growth.[101]

Figure 1.19 Rate of urban population growth, by global region, 2000–2050



Source: ECA elaboration from UN-Habitat data.

URBANIZATION, GROWTH, AND POVERTY

Amid these dynamics, urban areas have become key drivers of social and economic transformation. Between 2001 and 2020, they contributed an estimated 0.33 percentage points to the annual growth of GDP per capita—equivalent to 29 per cent of Africa's average annual GDP growth over the period. Yet despite contributing to economic growth, urbanization has not translated into broad-based social development, because poverty and inequality remain among the most persistent and complex challenges confronting African cities. Migrants to urban areas have been met with limited job opportunities, and many end up in low-income, informal employment.[102] Slums and informal settlements remain prominent features of the urban landscape.[103] Although the proportion of the urban population residing in slums has declined modestly, nearly 46 per cent of African urban residents still live in such conditions.[104] These people frequently endure one or more deprivations, including lack of access to improved water and sanitation sources, overcrowded and precarious housing, insecurity, and inadequate infrastructure.

Only 54 per cent of Africa's urban population has access to safely managed water, while a mere 23 per cent has access to safely managed sanitation.[105] Although some progress has been made in reducing the proportion of people living below nationally defined poverty lines in the past two decades, Africa faces the highest share of working poverty globally,[106] with more than 145 million people in extreme working poverty. On average, 80 per cent of the population continues to lack legal identity, economic, and social rights; affordable public services; and adequate social protection mechanisms.[107] Marginalized groups—including women, children, unhoused individuals, migrants, refugees, minorities, indigenous peoples, persons with disabilities, and those engaged in informal labour—remain particularly disadvantaged in accessing rights and opportunities.

URBANIZATION AND EMPLOYMENT

In 2018, while African employment represented 14 per cent of global employment, working poor people accounted for more than half of the world's working poor people.[108] Furthermore, the informal economy continues to dominate Africa's urban labour markets, with more than 80 per cent of employment generated in the informal sector, constituting the primary livelihood source for urban populations.[109] There are wide disparities in informal employment across African subregions: 22.7 per cent in Southern Africa, 46.3 per cent in East Africa, 56.6 per cent in North Africa, 59.3 per cent in Central Africa, and 78.1 per cent in West Africa.[110] Moreover, informality disproportionately affects vulnerable groups, including 95.8 per cent of young people ages 15–24, 92 per cent of women, and a large share of persons with disabilities.[111] Workers in this sector remain highly vulnerable to external shocks and market volatility, which result in unstable income and higher risk of poverty.

Looking ahead, Africa's labour force will expand considerably due to ongoing demographic and urbanization trends, as the working-age population is projected to grow from 224 million in 2030 to 730 million in 2050.[112] However, formal job creation has not kept pace with this rapid growth, raising concerns about the continent's ability to harness its demographic dividend.[113] Home to the youngest, growing, and quickly urban-based labour force, nearly 60 million young people are not in employment, education, or training, and almost 13 million are unemployed.[114] As a result, high informality and job insecurity are leading to high vulnerability in Africa's labour market.[115]

Africa has made some progress across several key socioeconomic indicators, but challenges remain acute in countries experiencing urbanization rates above the continental average (table 1.3). Rising poverty, overstretched infrastructure (such as electricity and water supply), mental health challenges, and restricted access to adequate housing and essential services such as healthcare and education remain key concerns in these countries.[116] The evidence underscores the complex interplay between urbanization and sustainable social development, highlighting that the pace and governance of urban growth are pivotal in shaping Africa's development outcomes.[117]

PROGRESS IN GENDER EQUALITY AND WOMEN'S EMPOWERMENT

Africa stands at a pivotal moment in its development trajectory. With the world's youngest population, rapid urbanization, and a burgeoning digital economy, frontier technologies such as artificial intelligence, data science, and financial technology hold immense potential to transform the continent's economic structures and lift millions of people out of poverty. Realising this transformative potential depends on the full participation of women, who constitute more than half the continent's population. But persistently wide gender gaps remain a major barrier to progress. While the world has closed nearly 68.8 per cent of the gender gap, Africa's Gender Equality Index stands at just 50.3 per cent—a stark reminder of the work that remains.[118] These gaps threaten to slow Africa's economic aspirations by limiting its ability to leverage innovation and drive inclusive growth.

Gender inequality is not just about an absence of rights; it also has substantial economic consequences, with an average cost of $95 billion a year in Africa since 2010 and a maximum annual cost of $105 billion (6 per cent of GDP) in 2014.[119] Discriminatory social institutions alone reduced GDP by nearly 7.5 per cent in 2019.[120] If all African countries had narrowed their gender gaps in 2021 to the levels of the best-performing country in the region—particularly the gaps in labour force participation and digital inclusion—the continent could have unlocked an additional $316 billion (10 per cent of the continent's GDP) by 2025.[121] Improving gender equality thus remains central to unlocking Africa's full economic potential and ensuring a more prosperous future for everyone on the continent.

Table 1.3 Africa's socioeconomic progress in the context of rapid urbanization

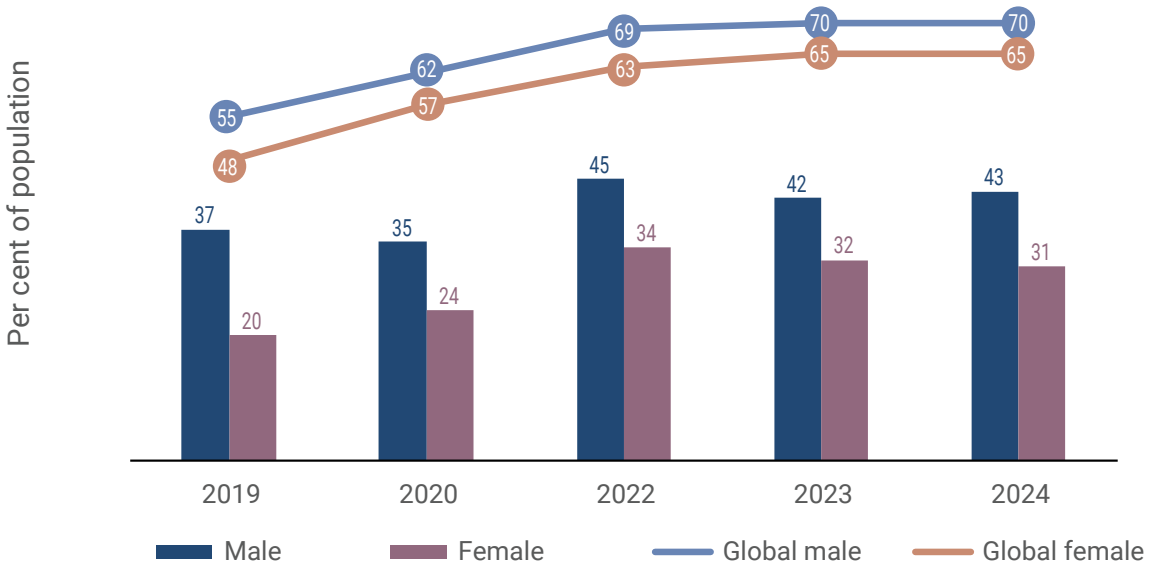
			2000		2020	
Variable	**Unit of measurement**	**Data source**	**Africa average in Africa**	**Average for countries whose urban population growth is above the continental average**	**Africa average in Africa**	**Average for countries whose urban population growth is above the continental average**
Access to electricity	Percentage of the urban population with access to electricity	World Bank	35	26	55	43
Access to drinking water	Percentage of urban population with access to drinking water	World Bank	39	34	50	43
Telecommunication	A composite index[a]	United Nations Department of Economic and Social Affairs	24	22	31	24
Out-of-pocket health spending	Percentage of current health spending borne by households	World Bank	47	47	34	39
National poverty headcount	Percentage of the population living below the national poverty line	World Bank	39	46	34	38
Pupil-teacher ratio	Average number of pupils per teacher in primary school	United Nations Educational, Scientific, and Cultural Organization	44	46	37	43
Employment in the service sector	Percentage of total employment	World Bank	34	30	42	35

a. The Telecommunication Index, a component of the e-Government Development Index designed by the United Nations Department of Economic and Social Affairs, captures the availability and penetration of telecommunication services in a country, including internet users, mobile cellular subscriptions, wireless broadband subscriptions, and broadband affordability.
Source: ECA elaboration from and UNDESA (2025), UNESCO (2025), and World Bank (2025e).

THE DIGITAL, TECHNOLOGY, AND GENDER DIVIDES

Gender digital divides persist across most of Africa, with limited progress towards closing them. Africa has the lowest share of internet users worldwide and the widest gender gaps in access. Despite some progress, the region still trails others by a wide margin, with only about 4 in 10 men and only 3 in 10 women online (figure 1.20). Limited connectivity compounds the existing inequalities in income, wealth, education, health, and opportunity. In 2023, Africa scored 0.76 on the International Telecommunication Union gender parity index—an improvement from 0.58 in 2018 but still the lowest score globally.

Figure 1.20 Internet users in Africa and globally, by gender, 2019–2024



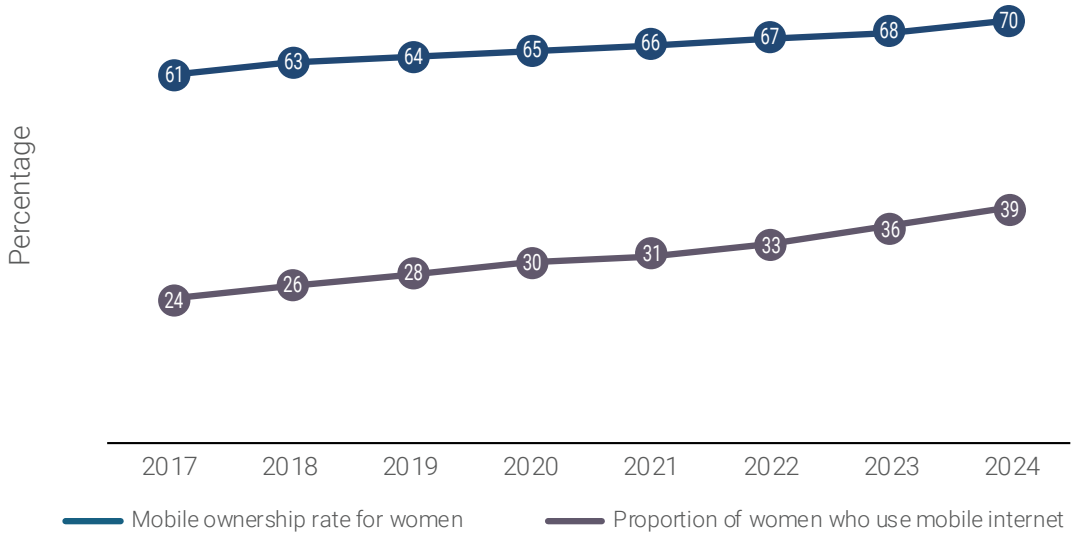
Note: Data for 2021 were not published because of the Covid-19 pandemic.
Source: International Telecommunication Union (2025a) compiled using data from Facts and Figures Reports.

Africa has the lowest share of internet users worldwide and the widest gender gaps in access. Despite some progress, the region still trails others by a wide margin, with only about 4 in 10 men and only 3 in 10 women online.

Poverty, exacerbated by prevailing social norms, remains a key driver of the gender digital divide, with the cost of broadband services and mobile phones posing a major barrier, especially for women.[122] In Nigeria, mobile broadband access greatly improved household welfare, increasing household food consumption by 6.2 per cent within a year and by 7.8 per cent after two years and increasing household non-food consumption by 6.3 per cent within a year and by 6.1 per cent after two years. For households living in extreme poverty, broadband access improved living conditions by 4.3 per cent in the first year and 6.9 per cent in the second.[123] These gains are attributed to higher labour force participation and employment opportunities, particularly for women, who are disproportionately concentrated in informal or vulnerable forms of employment.

Despite the positive impact of increased connectivity on socioeconomic outcomes, mobile phone ownership and mobile internet use remains low in Africa and is slowly increasing (figure 1.21).

Figure 1.21 Female mobile phone ownership and mobile internet use in Africa (excluding North Africa), 2017–2024



Source: Data from Global System for Mobile Communications Association (2024a). The Mobile Gender Gap Report 2025.

The low rates of mobile ownership and internet use by women across Africa are underpinned by a mix of socioeconomic, legal, and cultural barriers. Limited identification documents further hinder women's ability to register SIM cards.[124] For example, in Nigeria, 8 million fewer women than men held a national identity document in 2021.[125] Gender gaps in device ownership persist, with men more likely to own smartphones, while women tend to rely on feature or basic phones.[126] Household spending priorities also frequently favour men due to their greater bargaining power within households, leaving women with less control over communication expenses.[127] Social norms also compound these barriers: women may face restrictions on when and how they can use devices,[128] be confined to content deemed "appropriate," [129] or even lose access if subjected to harassment.[130] In some communities, mobile and social media use is synonymous and viewed as a threat to traditional gender roles, leading families to limit or discourage women's digital participation altogether.[131]

Despite the positive impact of increased connectivity on socioeconomic outcomes, mobile phone ownership and mobile internet use remains low in Africa and is slowly increasing.

WOMEN AND GIRLS STILL FACE CHALLENGES IN TECHNOLOGY AND INNOVATION

Women remain heavily underrepresented in key decisionmaking positions across Africa. As of 2024, they hold only 25 per cent of parliamentary seats, 24 per cent of cabinet positions, and just 13 per cent of top executive positions on the continent, with political party leadership averaging a mere 9 per cent—and much lower representation in North Africa.[132] These figures represent a modest increase over a three-year span, but they are still far from gender parity. In 2021, women held 24 per cent of parliamentary seats,

22 per cent of cabinet seats, and 7 per cent of top executive positions, with wide regional disparities. Rwanda stands out globally, with women holding more than 60 per cent of parliamentary seats, and Mozambique has achieved parity in cabinet positions, but many other countries remain well below the continental average.[133]

While advances in mobile connectivity and frontier technologies present new opportunities, the digital divide remains evident. As of 2023, women across Africa were 27.6 per cent less likely than men to use mobile internet,[134] despite mobile and digital platforms becoming the primary gateway to economic and social participation. Mobile phone ownership and mobile internet use among women and men in Africa rose between 2021 and 2024, and the average gender gap narrowed from 22.4 per cent for mobile phone ownership and 33.2 per cent for mobile internet use to 19.2 per cent in 2021 and 27.6 per cent in 2023.[135] The gap remains driven by affordability barriers, limited digital literacy, and prevailing social norms.

Deep-seated patriarchal cultural norms, social stereotypes, and policy shortcomings continue to constrain women's and girls' participation in innovation-driven sectors, perpetuating a cycle of exclusion.[136] Cultural and structural barriers influence girls' education and career choices, limiting their entry into science, technology, engineering, and mathematics (STEM)—fields essential for Africa's digital and data-driven future. Although Africa leads globally in women's share of STEM graduates (47 per cent compared with Europe's 42 per cent), entrenched social norms slow the transition into STEM employment, resulting in persistent underrepresentation in tech roles and leadership.[137] In rural and marginalized communities, these constraints are compounded by infrastructure deficits, safety concerns, and a lack of visible female role models in key sectors, all of which limit access to digital skills and advanced learning opportunities (chapter 5).[138]

Insufficient gender-disaggregated data, lack of targeted incentive systems and financial inclusion, and gender-blind macroeconomic policies restrict women's advancement in productive sectors and decisionmaking roles. The lack of reliable, up-to-date gender data restricts governments' and businesses' ability to design, monitor, and implement effective interventions.[139] In 2023, the labour force participation gender index score (which measures the gap between female and male workforce involvement) for Africa was 70.2 per cent, indicating major disparities in both formal and informal labour markets.[140]

Some African countries are emerging as models for empowering women and girls to leverage frontier technologies, illustrating the transformative impact on economic growth and innovation. Targeted reforms, inclusive policies, and innovative public-private partnerships have been used to unlock full digital potential in Ghana, Nigeria, Rwanda, and South Africa.[141]

CONCLUSION

Africa's economic outlook is positive in the short to medium term, underpinned by improving economic growth and easing inflationary pressure. Growth projections suggest an average increase of 4.1 per cent from 2025 to 2027, supported by public investment, trade, easing inflationary pressure, and stable currencies. But African countries continue to face both macroeconomic and structural vulnerabilities, including sovereign debt challenges, amid high borrowing costs, hindering sustainable development, as evidenced by the high number of countries in debt distress. Even though Africa has shown remarkable resilience in growth and resistance to external shocks, it is constrained by heightened global and regional risks and uncertainties, as well as geopolitical tensions. The recent global protectionist policies are expected to have adverse effects on the continent due to overarching uncertainty and disrupted trade dynamics. Despite the many success stories with regards to poverty reduction across the continent, poverty persists, coupled with increasing urbanization, high income inequality, and unemployment. But Africa's growing youth population offers enormous potential for global leadership, innovation, and economic growth.

Africa's economic outlook is positive in the short to medium term, underpinned by improving economic growth and easing inflationary pressure. Growth projections suggest an average increase of 4.1 per cent from 2025 to 2027, supported by public investment, trade, easing inflationary pressure, and stable currencies.

REFERENCES

Abdullahi, M., A. Ahmad, B. K. Pandey, and D. Pandey. 2024. "Digital Currency Adoption: A Comparative Analysis of Global Trends and the Nigerian eNaira Digital Currency." *SN Computer Science* 5 (5): 602. https://doi.org/10.1007/s42979-024-02882-6.

AfDB (African Development Bank). 2025a. *Africa's Macroeconomic Performance and Outlook – January 2025*. AfDB, Abidjan.

AfDB (African Development Bank). 2025b. *Africa's Macroeconomic Performance and Outlook: Making Africa's Capital Work Better for Africa's Development*. AfDB, Abidjan.

AfDB (African Development Bank) and ECA (United Nations Economic Commission for Africa). 2024. *Africa Gender Index 2023 Analytical Report: African Women in Times of Crisis*. AfDB and ECA, Abidjan and Addis Ababa.

African Peer Review Mechanism and ECA (United Nations Economic Commission for Africa). 2024. *Africa Sovereign Credit Rating Outlook: 2024 End-Year Outlook*. Report No. G&SR-CRA04/2024 Year-End Review, 10th Edition. African Peer Review Mechanism and ECA, Addis Ababa. https://aprm.au.int/sites/default/files/files/2025-02/10th-edition-csr-eng.pdf.

African Peer Review Mechanism and ECA (United Nations Economic Commission for Africa). 2025. *Africa Sovereign Credit Rating Outlook Report: 2025 End-Year Outlook*. Report No. G&SR-CRR011/2025, 12th Edition. African Peer Review Mechanism and ECA, Addis Ababa. https://repository.uneca.org/entities/publication/8ccba37a-2604-48e1-b1ff-f8c450dce754.

Alkire, S., R. Mishra, L. Selden, and N. Suppa. 2025. *The Global Multidimensional Poverty Index (MPI) 2025 Country Results and Methodological Note*. OPHI MPI Methodological Note 61. Oxford Poverty and Human Development Initiative (OPHI), University of Oxford, Oxford. https://ophi.org.uk/global-mpi/2024. https://ophi.org.uk/global-mpi/2025.

Amaglobeli, D., R. A. de Mooij, A. Mengistu, M. Moszoro, M. Nose, S. Nunhuck, S. Pattanayak, L. R. del Paso, F. Solomon, R. Sparkman, H. Tourpe, and G. Uña. 2025. Transforming Public Finance Through GovTech. Staff Discussion Note 2023/004. IMF (International Monetary Fund), Washington, DC. https://doi.org/10.5089/9798400245480.006.

Anazia, C. N., and C. C. Nwachukwu. 2025. "The Impact of Mobile and Payment Card Technology on Economic Growth and Development in Developing Countries, Using M-Pesa as a Case Study." *IIARD International Journal of Banking and Finance Research* 11 (4).

Ashraf, N., O. Bandiera, V. Minni, and M. Quintas-Martinez. 2024. "Gender Gaps Across the Spectrum of Development: Local Talent and Firm Productivity." *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4883862.

AUC (African Union Commission) and OECD (Organisation for Economic Co-operation and Development). 2025. *Africa's Development Dynamics 2025: Infrastructure, Growth and Transformation*. AUC and OECD, Addis Ababa and Paris.

Bahia, K., P. Castells, G. Cruz, T. Masaki, X. Pedros, T. Pfutze, C. C. Rodriguez, and H. J. Winkler-Seales. 2020. "The Welfare Effects of Mobile Broadband Internet: Evidence from Nigeria." Policy Research Working Paper 9230. World Bank, Washington, DC.

Bank of Ghana. 2025. *MPC Press Release*. Bank of Ghana, Accra. https://www.bog.gov.gh/wp-content/uploads/2025/03/MPC-Press-Statement-March-2025-1.pdf.

Bank of Uganda. 2025. *MPC Statement*. Bank of Uganda, Kampala. https://www.bou.or.ug/bouwebsite/bouwebsitecontent/MonetaryPolicy/Monetary_Policy_Statements/2025/MPS-November-2025.pdf.

Bank of Zambia. 2025. *Monetary Policy Statement*. Bank of Zambia, Lusaka. https://www.boz.zm/MPC_Statement_for_Q1_2025.pdf.

Barrdear, J., and M. Kumhof. 2016. "The Macroeconomics of Central Bank Issued Digital Currencies." Bank of England Staff Working Paper 605. Bank of England, London. https://doi.org/10.2139/ssrn.2811208.

Benítez, J. C., M. Mansour, and C. Vellutini. 2023. Building Tax Capacity in Developing Countries. Staff Discussion Note SDN/2023/006. IMF (International Monetary Fund), Washington, DC. https://www.imf.org/en/Publications/Staff-Discussion-Notes/Issues/2023/09/15/Building-Tax-Capacity-in-Developing-Countries-535449.

Bloomberg. 2025. "Senegal Raises $644 Million in Local Currency Bond Sale." https://www.bloomberg.com/news/articles/2025-07-16/senegal-raises-644-million-in-cfa-franc-government-bond-issue.

Borrowman, M., B. Jonathan, H. Kelsey, and L. R. Aishwarya. 2025. Gender Gaps and Structural Transformation in a New Development Era. Yale Economic Growth Center, New Haven, CT. https://egc.yale.edu/news/250627/gender-gaps-and-structural-transformation-new-development-era.

Burga, L., N. Gimelli, S. M. A. Robakowski, M. Miller, M. Rawlins, and G. Snyder. 2021. *Using Digital Solutions to Address Barriers to Female Entrepreneurship: A Toolkit*. World Bank, Washington, DC.

Cattaneo, A., and S. Robinson. 2020. "Multiple Moves and Return Migration Within Developing Countries: A Comparative Analysis." *Population, Space and Place* 26 (7): e2335.

Central Bank of Egypt. 2025a. *MPC Statement*. Central Bank of Egypt, Cairo. https://www.cbe.org.eg/en/news-publications/news/2025/12/25/15/51/mpc-press-release-25-december-2025.

Central Bank of Egypt. 2025b. *Monetary Policy Report Q1 – 2025*. Central Bank of Egypt, Cairo. https://www.cbe.org.eg/-/media/project/cbe/listing/publication/monetary-policy-report/2025/monetary-policy-report--q1-2025.pdf.

Central Bank of Kenya. 2025a. *MPC Statement*. Central Bank of Kenya, Nairobi. https://www.centralbank.go.ke/uploads/mpc_press_release/1156181278_MPC per cent20Press per cent20Release per cent20- per cent20Meeting per cent20of per cent20December per cent209 per cent202025.pdf.

Central Bank of Kenya. 2025b. *Thirty Fourth Bi-Annual Report of the Monetary Policy Committee*. Central Bank of Kenya, Nairobi. https://www.centralbank.go.ke/uploads/monetary_policy_reports/301734411_34th.pdf.

Central Bank of Nigeria. 2025. *Monetary Policy Decisions*. Central Bank of Nigeria, Abuja. https://www.cbn.gov.ng/MonetaryPolicy/decisions.html.

Chuku, C., and M. Y. Yenice. 2021. "Eurobonds, Debt Sustainability and Macroeconomic Performance in Africa: Synthetic Controlled Experiments." Working Paper Series No. 356. African Development Bank Group, Abidjan.

Donald, A., T. Koroknay Palicz, M. Goldstein, and M. Sage. 2023. "The Fertility Impacts of Development Programs." Policy Research Working Paper. World Bank, Washington, DC. https://documents1.worldbank.org/curated/en/099518407102437684/pdf/IDU1699f7acb-16ca614fe4199601d8d3c9a94a76.pdf.

Du Preez, P. 2026. "Algeria: Lower Hydrocarbon Prices Spell Trouble for the Economy." https://my.oxfordeconomics.com/reportaction/c4F78E247f554F3E8751e6/Toc?SearchTerms=oil per cent20exporting.

Econfin Agency. 2025. "Côte d'Ivoire Secures Better CFA Bond Rates Abroad than in WAEMU." https://www.ecofinagency.com/finance/2703-46553-cote-d-ivoire-secures-better-cfa-bond-rates-abroad-than-in-waemu.

ECA (United Nations Economic Commission for Africa). 2019. *Economic Report on Africa: Tax Reform, Digitization Key to Financing Africa's Development*. ECA, Addis Ababa.

ECA (United Nations Economic Commission for Africa). 2024. *Background Report on the Sub-Theme of No Poverty*. Africa Regional Forum on Sustainable Development, Tenth Session, Addis Ababa. https://www.uneca.org/eca-events/sites/default/files/resources/documents/TCND/ARFSD2024/Background/background_paper_on_sdg1_en.pdf.

ECA (United Nations Economic Commission for Africa). 2025a. *The Effects of ODA Cutbacks in Eastern Africa's Programmes and Development Outcomes: What Do We Know?* ECA, Addis Ababa. https://www.uneca.org/eca-events/sites/default/files/resources/documents/sro-ca/ce-icsoe2025/icsoe_background_document3_the_effects_of_oda_29sep2025_34.pdf.

ECA (United Nations Economic Commission for Africa). 2025b. *Enhancing Domestic Resource Mobilization Through Innovation and Technology in North Africa*. ECA/SRO-NA/ICSOE/40/3. ECA, Addis Ababa. https://www.uneca.org/eca-events/sites/default/files/resources/251106_icsoe-2025-comcept-note-en.pdf.

ECA (United Nations Economic Commission for Africa), AUC (African Union Commission), and UNDP (United Nations Development Programme). 2025. *Africa Sustainable Development Report: Advancing Sustainable, Inclusive, Science- and Evidence-Based Solutions for the 2030 Agenda for Sustainable Development and Its Sustainable Development Goals for Leaving No One Behind, and the African Union's Agenda 2063*. UNDP, New York. https://www.undp.org/africa/publications/2025-africa-sustainable-development-report.

Esterhuysen, L. 2025a. "Ghana Policymakers to Enter 2026 on the Front Foot." https://my.oxfordeconomics.com/reports/5795eA72228e4c0aBa2E64/aPolicymakerstoe#r::5795eA72228e4c0aBa2E64:GhanaPolicymakerstoe:Forecastoverview:Recentdevelopments.

Esterhuysen, L. 2025b. "Ghana: Government Zones in on Gold Sector Reform." https://my.oxfordeconomics.com/reports/aB1c444eD1Bf4Afa9308B2/GhanaGovernmentzones?searchHighlight=africa#aB1c444eD1Bf4Afa9308B2:GhanaGovernmentzones:Forecastoverview.

FAO (Food and Agriculture Organization of the United Nations). 2018. *Gender and ICTs: Mainstreaming Gender in the Use of Information and Communication Technologies (ICTs) for Agriculture and Rural Development*, by S. Treinen and A. Van der Elstraeten. FAO, Rome.

Farquhar, C. 2025. "The Gambia: Growth Remains Buoyant amid Global Uncertainty." https://my.oxfordeconomics.com/reportaction/ae0E1dDbfb3348458Aa420/Toc.

Filani, O. M., O. Elebe, C. C. Imediegwu, A. Okesiji, and O. Oyasiji. 2021. "Digital Currencies and Monetary Policy: Implications for Central Banks in Africa." *Journal of Frontiers in Multidisciplinary Research* 2 (1): 346–358.

Franken, C. 2025. "Angola: Oil Supply Glut Will Dampen the Economy Next Year." https://my.oxfordeconomics.com/reportaction/b23296cFC57C41AC8e187d/Toc?SearchTerms=oil per cent20exporting.

Gillwald, A., F. Odufuwa, and O. Mothobi. 2018. *The State of ICT in Nigeria*. Policy Paper No. 3; Series 5: After Access – Assessing Digital Inequality in Africa. Research ICT Africa, Cape Town. https://researchictafrica.net/2018/12/19/the-state-of-ict-in-nigeria-2018/.

Gillwald, A., and A. Partridge. 2022. *Gendered Nature of Digital Inequality: Evidence for Policy Considerations*. Background Document for UN Women Expert Group Meeting "Innovation and Technological Change, and Education in the Digital Age for Achieving Gender Equality and the Empowerment of All Women and Girls." Research ICT Africa, Cape Town.

GSMA (Global System for Mobile Communications Association). 2022. *The Mobile Gender Gap Report 2022*. GSMA, London.

GSMA (Global System for Mobile Communications Association). 2024a. *The Mobile Gender Gap Report 2025*. GSMA, London. https://www.gsma.com/r/gender-gap/.

GSMA (Global System for Mobile Communications Association). 2024b. "Kenya's Digital Economy to Contribute KSH 662 Billion to GDP by 2028, Driven by Policy Reforms." https://www.gsma.com/newsroom/press-release/kenyas-digital-economy-to-contribute-ksh-662-billion-to-gdp-by-2028-driven-by-policy-reforms/.

GSMA (Global System for Mobile Communications Association). 2025a. *Mobile Money Evaluation: Kenya – Country Brief 2024*. GSMA, London.

GSMA (Global System for Mobile Communications Association). 2025b. *Mobile Money's Impact on Economic Growth in Five African Markets*. GSMA, London.

Guven, M., and R. Karlen. 2020. "Supporting Africa's Urban Informal Sector: Coordinated Policies with Social Protection at the Core." *World Bank Blog*. https://blogs.worldbank.org/africacan/supporting-africas-urban-informal-sector-coordinated-policies-social-protection-core.

Hakizimana, N., and F. Santoro. 2024. "Technology Evolution and Tax Compliance: Evidence from Rwanda." https://www.ictd.ac/publication/technology-evolution-and-tax-compliance-evidence-from-rwanda/.

Hassan, B., T. Unwin, and A. Gardezi. 2018. "Understanding the Darker Side of ICTs: Gender, Sexual Harassment, and Mobile Devices in Pakistan." *Information Technologies and International Development* 14: 1–17.

Harman, O., et al. 2022. "Sustainable Urbanisation in Developing Countries: Cities as Places to Live." Brief, IGC. https://www.theigc.org/publications/sustainable-urbanisation-developing-countries-cities-places-live.

IFC (International Finance Corporation). 2025. "IFC Invests in Lagos Free Zone to Support Industrial Growth and Economic Diversification in Nigeria." https://www.ifc.org/en/pressroom/2025/ifc-invests-in-lagos-free-zone-to-support-industrial-growth-and-economic-diversifi.

IFC (International Finance Corporation) and UNESCO (United Nations Educational, Scientific and Cultural Organization). 2025. *Closing the Gender Gap in Education and Employment*. IFC and UNESCO, Washington, DC.

ILO (International Labour Organization). 2018a. *Women and Men in the Informal Economy: A Statistical Picture*. 3rd ed. ILO, Geneva. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/publication/wcms_626831.pdf.

ILO (International Labour Organization). 2018b. *Care Work and Care Jobs for the Future of Decent Work*. ILO, Geneva. https://www.ilo.org/global/publications/books/WCMS_633135/lang--en/index.htm.

ILO (International Labour Organization). 2022. "New ILO Database Highlights Labour Market Challenges of Persons with Disabilities." https://ilostat.ilo.org/blog/new-ilo-database-highlights-labour-market-challenges-of-persons-with-disabilities/#:~:text=Persons per cent20with per cent20disabilities per cent20are per cent20more per cent20likely per cent20to per cent20work per cent20in per cent20the,an per cent20even per cent20more per cent20vulnerable per cent20situation.

ILO (International Labour Organization). 2023. "African Youth Face Pressing Challenges in the Transition from School to Work." ILO, Geneva. https://ilostat.ilo.org/african-youth-face-pressing-challenges-in-the-transition-from-school-to-work/.

ILO (International Labour Organization). 2024. *World Employment and Social Outlook: September 2024 Update*. ILO, Geneva. https://www.ilo.org/publications/flagship-reports/world-employment-and-social-outlook-september-2024-update.

ILO (International Labour Organization). 2025. "Overview of the Informal Economy in Africa." ILO, Geneva. https://researchrepository.ilo.org/esploro/outputs/encyclopediaEntry/Overview-of-the-informal-economy-in/995640098602676

IMF (International Monetary Fund). 2020. *Regional Economic Outlook, April 2020: Sub-Saharan Africa, COVID-19: An Unprecedented Threat to Development*. IMF, Washington, DC.

IMF (International Monetary Fund). 2022. *Fiscal Rules Dataset*. IMF, Washington, DC. https://www.imf.org/external/datamapper/fiscalrules/reference.htm.

IMF (International Monetary Fund). 2024. *Gender Equality and Economic Development in Sub-Saharan Africa*. IMF, Washington, DC. https://doi.org/10.5089/9798400246968.071.

IMF (International Monetary Fund). 2025a. *World Economic Outlook Database, October 2025*. IMF, Washington, DC. https://data.imf.org/en/Data-Explorer?datasetUrn=IMF.RES:WEO(9.0.0).

IMF (International Monetary Fund). 2025b. *Central African Economic and Monetary Community: Press Release; Staff Report; and Statement by the Executive Director*. IMF, Washington, DC.

IMF (International Monetary Fund). 2025c. "IMF Staff Concludes Visit to Senegal." Press Release No. 25/282. IMF, Washington, DC. https://www.imf.org/en/News/Articles/2025/08/26/pr25282-senegal-imf-staff-concludes-visit#:~:text= per cent22Despite per cent20these per cent20fiscal per cent20challenges per cent2C per cent20Senegal's,the per cent20Sangomar per cent20and per cent20GTA per cent20fields.

IMF (International Monetary Fund). 2025d. "IMF Staff Completes 2025 Article IV Mission with Nigeria." Press Release No. 25/231. IMF, Washington, DC. https://www.imf.org/en/News/Articles/2025/07/01/pr-25231-nigeria-imf-staff-completes-2025-article-iv-mission.

IMF (International Monetary Fund). 2025e. IMF Data. IMF, Washington, DC. https://data.imf.org/en/Data-Explorer.

IMF (International Monetary Fund). 2025f. Cameroon: Eighth Reviews Under the Extended Arrangement Under the Extended Fund Facility and the Arrangement Under the Extended Credit Facility, and Third Review Under the Resilience and Sustainability Facility Arrangement—Press Release; Staff Report; and Statement by the Executive Director for Cameroon. IMF Staff Country Reports 2025/222. IMF, Washington, DC.

IMF (International Monetary Fund). 2025g. "IMF Executive Board Approves a New 48-Month Extended Credit Facility (ECF) Arrangement for Chad." Press Release No. 25/269. IMF, Washington, DC. https://www.imf.org/en/

news/articles/2025/07/25/pr25269-chad-imf-executive-board-approves-a-new-48-month-ecf-arrangement.

IMF (International Monetary Fund). 2025h. Zambia: 2025 Article IV Consultation, Fifth Review Under the Extended Credit Facility Arrangement, and Financing Assurances Review—Press Release; Staff Report; and Statement by the Executive Director for Zambia. IMF Staff Country Reports 2025/225. IMF, Washington, DC. https://www.imf.org/en/Publications/CR/Issues/2025/08/05/Zambia-2025-Article-IV-Consultation-Fifth-Review-Under-the-Extended-Credit-Facility-569341.

International Institute for Democracy and Electoral Assistance. 2024. *Women's Political Participation: Africa Barometer 2024: Second Edition*. International IDEA, Stockholm.

ITU (International Telecommunication Union). 2022. "Rwanda Is Tackling Digital Development Challenges—and Succeeding." https://www.itu.int/hub/2022/06/kigali-rwanda-digital-development-milestones/.

ITU (International Telecommunication Union). 2025a. *Measuring Digital Development: Facts and Figures 2024*. ITU, Geneva. https://www.itu.int/en/ITU-D/Statistics/Pages/facts/default.aspx.

ITU (International Telecommunication Union). 2025b. "Individuals Owning a Mobile Phone by Gender." ITU DataHub. ITU, Geneva. www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx.

International Trade Administration. 2024. "South Africa Digital Economy Overview." https://www.trade.gov/country-commercial-guides/south-africa-digital-economy.

Jarrahi, J. 2021. „Massive Gender Disparities in Digital ID Systems Persist."

Jelagat, H. 2024. "Kenya Signs a Financing Agreement with Republic of Korea for the Development of a Digital Media City at Konza Technopolis." https://konza.go.ke/kenya-signs-a-financing-agreement-with-republic-of-korea-for-the-development-of-a-digital-media-city-at-konza-technopolis/.

Kenya Revenue Authority. 2023. "Digital Transformation: The Emerging Use of Artificial Intelligence." https://www.kra.go.ke/news-center/blog/1997-digital-transformation-the-emerging-use-of-artificial-intelligence.

Kenya Revenue Authority. 2025. *KRA Online Services*. Kenya Revenue Authority, Nairobi. https://www.kra.go.ke/our-online-services.

Lakner, C., M. C. Nguyen, F. Alfani, D. V. Aron, A. Atamanov, et al. 2025. "June 2025 Update to the Poverty and Inequality Platform (PIP): What's New?" https://documents1.worldbank.org/curated/en/099510306052516849/pdf/IDU-eb272b02-ecd1-4633-9e37-9297e20a711c.pdf.

Lawler, A. 2025. "OPEC Shifts Oil Outlook to See Small Surplus in 2026." https://www.reuters.com/business/energy/opec-sees-balanced-oil-market-2026-moves-further-away-deficit-projection-2025-11-12/.

Mayowa, K., U. Bagus, and K. Dharmadhikary. 2025. *Closing the Loop: The Quest for Gender Parity in African Tech*. McKinsey & Company.

Mitchener, K. J., and C. Trebesch. 2022. Sovereign Debt in the 21st Century. Kiel Working Paper No. 2198 (revised 2022). Kiel Institute for the World Economy, Kiel. https://www.kielinstitut.de/publications/sovereign-debt-in-the-21st-century-6749.

Morgan Stanley. 2025. "The Depreciation of the Dollar." https://www.morganstanley.com/insights/articles/us-dollar-declines.

MTN Group Limited. 2025. *Annual Financial Results for the Year Ended 31 December 2024*. MTN Group Limited, Johannesburg. https://mtn-investor.com/fy-2024-reporting-suite/pdf/annual-financial-results-2025.pdf.

National Bank of Ethiopia. 2025. *Monetary Policy Committee Meeting No. 5*. National Bank of Ethiopia, Addis Ababa. https://nbe.gov.et/nbe_news/press-release-monetary-policy-committee-meeting-no-5/.

National Bank of Rwanda. 2025. *MPC Press Release*. National Bank of Rwanda, Kigali. https://www.bnr.rw/documents/MPC_Press_Release__Feb._2025_English.pdf.

Ndung'u, N. 2025. "Fintech, Savings, and Financial Inclusion in Sub-Saharan Africa." In *The Domestic Savings Shortfall in Sub-Saharan Africa*, edited by R. Ngugi and K. Sen. Oxford University Press, Oxford. https://doi.org/10.1093/oso/9780198932482.003.0002.

OECD (Organisation for Economic Co-operation and Development). 2021. *SIGI 2021 Regional Report for Africa: Social Institutions and Gender Index*. OECD Publishing, Paris. https://doi.org/10.1787/a6d95d90-en.

OECD (Organisation for Economic Co-operation and Development). 2026. *OECD Data Explorer*. OECD, Paris.

OECD (Organisation for Economic Co-operation and Development), ECA (United Nations Economic Commission for Africa), and AfDB (African Development Bank). 2022. *Africa's Urbanisation Dynamics 2022: The Economic Power of Africa's Cities*. West African Studies. OECD Publishing, Paris. https://doi.org/10.1787/3834ed5b-en.

OPHI (Oxford Poverty and Human Development Initiative) and UNDP (United Nations Development Programme). 2024. *2024 Global Multidimensional Poverty Index (MPI): Poverty amid Conflict*. UNDP, New York. https://hdr.undp.org/system/files/documents/hdp-document/mpireport2024en.pdf.

OPHI (Oxford Poverty and Human Development Initiative) and UNDP (United Nations Development Programme). 2025. *Global Multidimensional Poverty Index 2025 – Overlapping Hardships: Poverty and Climate Hazards*. OPHI and UNDP, Oxford and New York. https://ophi.org.uk/publications/gMPI16-2025.

Oula, S., E. Carey, and R. Kayibanda. 2016. "FinScope Insights: Women and Financial Inclusion in Rwanda: Promoting Greater Financial Inclusion of Women in Rwanda." Access to Finance Rwanda.

PAPSS (Pan-African Payment and Settlement System). 2025. *Press Releases*. PAPSS. https://papss.com/media/.

PwC (PricewaterhouseCoopers). 2025. *Global Economic Policy Changes and Implications for Nigeria*. PwC. https://www.strategyand.pwc.com/a1/en/assets/pdf/

ng-economic-outlook/global-economic-policy-changes-implications-for-nigeria.pdf.

Raithatha, R., and G. Storchi. 2025. *State of the Industry Report on Mobile Money 2025*. GSMA (Global System for Mobile Communications Association), London. https://www.gsma.com/sotir/wp-content/uploads/2025/04/The-State-of-the-Industry-Report-2025_English.pdf.

Ratha, D., V. Chandra, E. J. Kim, S. Plaza, and A. Mahmood. 2024. *Remittances Slowed in 2023, Expected to Grow Faster in 2024*. World Bank, Washington, DC.

Remitscope. 2025. *Remittance Data*. https://remitscope.org/africa/.

Reserve Bank of Zimbabwe (RBZ). 2025. *Resolutions of the Monetary Policy Committee Meeting Held on 01 December 2025*. RBZ, Harare. https://www.rbz.co.zw/documents/press/2025/MPC_COMMUNIQUE_December_2025_251202_090221.pdf.

Reuters. 2021. "Egypt Says Reviewing $23 Billion High-Speed Train Network with Siemens." https://www.reuters.com/article/world/middle-east/egypt-says-reviewing-23-billion-high-speed-train-network-with-siemens-idUSKBN29I2V9/.

Reuters. 2025a. "OPEC+ Set to Agree July Oil Output Hike This Week, Sources Say." https://www.reuters.com/business/energy/opec-set-agree-july-oil-output-hike-this-week-sources-say-2025-05-27/.

Reuters. 2025b. "Egyptian Pound Steadies After Devaluation, IMF Deal." https://www.reuters.com/world/africa/egyptian-pound-stable-after-devaluation-imf-deal-2024-03-07/.

Reuters. 2025c. "Zimbabwe on Track for 6 per cent Growth as Economy Recovers from Drought." https://www.reuters.com/world/africa/zimbabwe-track-6-growth-economy-recovers-drought-2025-07-31/#:~:text=HARARE per cent2C per cent20July per cent2031 per cent20(Reuters),Sign per cent20up per cent20here.

Rwanda Revenue Authority. 2019. *An Analysis of Discrepancies in Taxpayers' VAT Declarations in Rwanda*. Rwanda Revenue Authority, Kigali. https://rra.gov.rw/fileadmin/user_upload/7._an_analysis_of_discrepancies_in_taxpayers__vat_declarations_in_rwanda.pdf.

Safaricom PLC. 2023. *Annual Report and Financial Statements 2023*. Safaricom PLC, Nairobi. https://www.safaricom.co.ke/images/Downloads/2023-Safaricom-Annual-Report.pdf.

Seekings, J. Forthcoming. "Modern Guide on Urban Poverty." In *Modern Guide on Urban Poverty*, edited by D. Benassi, E. Mingione, and E. Morlicchio. Edward Elgar, Cheltenham.

Smit-Lengton, S. 2025. "East Africa: Juggling Reform, Revenue, and Restraint in 2025/26 Budgets." https://my.oxfordeconomics.com/reportaction/047aD96813344BC480093A/Toc.

South African Reserve Bank. 2025. *Quarterly Bulletin, June 2025*. South African Reserve Bank, Pretoria. https://www.resbank.co.za/en/home/publications/publication-detail-pages/quarterly-bulletins/quarterly-bulletin-publications/2025/june.

South African Revenue Service. 2023. "SARS Welcomes the MTBPS Revenue Announcement." https://www.sars.gov.za/media-release/sars-welcomes-the-mtbps-revenue-announcement-2/.

South African Revenue Service. 2024. "Compliance Efforts of SARS Bear Fruit and Underpin the Positive Revenue Results despite the Tough Prevailing Economic Conditions." https://www.sars.gov.za/media-release/compliance-efforts-of-sars-bear-fruit-and-underpin-the-positive-revenue-results-despite-the-tough-prevailing-economic-conditions/.

Stewart, R., B. Wright, L. Smith, S. Roberts, and N. Russell. 2021. "Gendered Stereotypes and Norms: A Systematic Review of Interventions Designed to Shift Attitudes and Behaviour." *Heliyon* 7 (4): e06660. https://doi.org/10.1016/j.heliyon.2021.e06660.

Strategy&. 2025. "South African Economic Outlook." https://www.strategyand.pwc.com/a1/en/insights/south-africa-economic-outlook.html.

United Nations. 2018. *World Economic and Social Survey 2018: Frontier Technologies for Sustainable Development*. E/2018/50/Rev.1 ST/ESA/370. United Nations, New York.

United Nations. 2024. *Unpacking Africa's Debt: Towards a Lasting and Durable Solution*. United Nations, New York.

United Nations. 2025. *UNData*. United Nations, New York. https://data.un.org/.

United Nations. 2026. *World Economic Situation and Prospects 2026*. United Nations, New York.

UNCTAD (United Nations Conference on Trade and Development). 2025a. *World Investment Report: International Investment in the Digital Economy*. United Nations, Geneva. https://unctad.org/system/files/official-document/wir2025_overview_en.pdf.

UNCTAD (United Nations Conference on Trade and Development). 2025b. *A World of Debt: It Is Time for Reform*. UNCTAD, Geneva. https://unctad.org/publication/world-of-debt.

UNCTAD (United Nations Conference on Trade and Development). 2025c. *UNCTADstat Database*. UNCTAD, Geneva. https://unctadstat.unctad.org/datacentre/.

UNDESA (United Nations Department of Economic and Social Affairs). 2025. *UN E-Government Knowledgebase*. UNDESA, New York. https://publicadministration.un.org/egovkb/en-us/Data-Center.

UNDP (United Nations Development Programme). 2016. *Africa Human Development Report 2016: Accelerating Gender Equality and Women's Empowerment in Africa*. UNDP, New York.

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2025. *Data Browser*. UNESCO, Paris. https://databrowser.uis.unesco.org.

UN-Habitat (United Nations Human Settlements Programme). 2022. *World Cities Report 2022*. UN-Habitat, Nairobi. https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf.

UN-Habitat (United Nations Human Settlements Programme). 2024. *World Cities Report 2024*. UN-Habitat, Nairobi. https://unhabitat.org/sites/default/files/2024/11/wcr2024_-_full_report.pdf.

Verster, B. 2025. "Economic Growth Notches a Gear in Q1." Talking Point–Nigeria, 22 July 2025.

Verster, B. 2025a. "Africa: Forecaster's Note – Currency Weakness Heats Price Pressures." https://my.oxfordeconomics.com/reportaction/73567fF59834430fa7fA31/Toc?SearchTerms=central per cent20bank.

Verster, B. 2025b. "Non-Oil Economy Gives Lifeline Ahead of Oil Price Slide." https://my.oxfordeconomics.com/reports/F5974F771B1e49128218d8/NigeriaNon-oileconom?searchHighlight=oil per cent20exporting#F5974F771B1e49128218d8:NigeriaNon-oileconom:Forecastoverview.

Vookoti, S. 2013. "BMW Recalled Its GPS System as German Men Refused to Take Directions from Female Voice." Hoax or Fact, 7 August 2013.

WHO (World Health Organization). 2018. "9 out of 10 People Worldwide Breathe Polluted Air, but More Countries Are Taking Action." https://www.who.int/news/item/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action.

WFP (World Food Programme). 2025. *Emergencies*. WFP. https://www.wfp.org/emergencies/ethiopia-emergency; https://www.wfp.org/emergencies/somalia-emergency; https://www.wfp.org/emergencies/south-sudan-emergency.

World Bank. 2019. "World Bank Guarantees Help Benin Refinance Expensive Debt & Address Health, Education Needs: A Win-Win." https://blogs.worldbank.org/en/ppps/world-bank-guarantees-help-benin-refinance-expensive-debt-address-health-education-needs-win-win.

World Bank. 2020. *Infrastructure Governance Assessment Framework (December 2020)*. World Bank, Washington, DC. https://thedocs.worldbank.org/en/doc/96550c14d62154355b6edc367d4d7f33-0080012021/original/Infrastructure-Governance-Assessment-Framework-December-2020.pdf.

World Bank. 2024. "Côte d'Ivoire's Debt-for-Development Swap, Enabled by the World Bank Group, Will Free up Funds for Education." https://www.worldbank.org/en/news/press-release/2024/12/05/c-te-d-ivoire-s-debt-for-development-swap-enabled-by-the-world-bank-group-will-free-up-funds-for-education?utm_source=chatgpt.com.

World Bank. 2025a. *Pink Sheet – Commodity Markets*. World Bank, Washington, DC. https://www.worldbank.org/en/research/commodity-markets#3.

World Bank. 2025b. *Improving Governance and Delivering for People in Africa*. *Africa's Pulse*, No. 31 (April 2025). World Bank, Washington, DC.

World Bank. 2025c. *Morocco Economic Update: Prioritizing Reforms to Boost the Business Environment*. World Bank, Washington, DC. https://openknowledge.worldbank.org/server/api/core/bitstreams/203057ba-9960-45a4-8241-e9793b12f2eb/content.

World Bank. 2025d. *Algeria*. World Bank, Washington, DC. https://thedocs.worldbank.org/en/doc/65cf93926fdb3ea23b72f277fc249a72-0500042021/related/mpo-dza.pdf.

World Bank. 2025e. *Open Data*. World Bank, Washington, DC. https://data.worldbank.org/.

World Bank. 2025f. *What Works to Advance Women's Digital Literacy? A Review of Good Practices and Programs*. World Bank, Washington, DC.

World Bank. 2025g. "Guinea Economic Update: Domestic Resource Mobilization and Management for Inclusive and Sustainable Development." https://www.worldbank.org/en/news/press-release/2025/07/01/guinea-economic-update-domestic-resource-mobilization-and-management-for-inclusive-and-sustainable-development.

World Bank. 2025h. *World Development Indicators*. World Bank, Washington, DC. https://databank.worldbank.org/source/world-development-indicators.

World Bank. 2025i. *Poverty and Inequality Platform*. World Bank, Washington, DC. https://pip.worldbank.org.

World Bank. 2025j. *Niger Economic Situation*. World Bank, Washington, DC. https://www.worldbank.org/ext/en/country/niger#tab-economy.

World Economic Forum. 2025. *The Global Gender Gap Report 2025*. World Economic Forum, Geneva.

World Inequality Lab. 2025. *World Inequality Database*. World Inequality Lab. https://wid.world.

Zottel, S. 2021. "Here Is a We-Fi Innovative Approach That Helps Unlock Commercial Financing and Dreams for Women-Led Businesses in Nigeria." *Africa Can End Poverty*, World Bank Blogs. https://blogs.worldbank.org/en/africacan/here-we-fi-innovative-approach-helps-unlock

END NOTES

1 Frontier technologies generally refer to cutting-edge, transformative, rapidly growing, and evolving technologies that can have a considerable impact on societies, economies, and the environment (United Nations 2018).

2 International Finance Corporation 2025; Jelagat 2024; Reuters 2021.

3 Reuters 2025a.

4 Franken 2025; Du Preez 2026; Verster 2025b.

5 Lawler 2025.

6 Smit-Lengton 2025.

7 International Monetary Fund 2025c.

8 World Bank 2025j.

9 World Bank 2025g.

10 IMF 2025d.

11 Verster 2025.

12 AUC and OECD 2025.

13 Strategy& 2025.

14 IMF 2025h; Reuters 2025c.

15 Based on the frontier technology index, a measure of technology and innovation developments that integrates five components: ICT deployment (infrastructure availability and quality), skills (education and labour market capabilities), research and development activity (publications and patents in 17 frontier technology areas), industry activity (high-tech manufacturing, ICT, and digital services), and access to finance (domestic credit to the private sector).

16 International Trade Administration 2024.

17 Anazia and Nwachukwu 2025.

18 GSMA 2024b.

19 GSMA 2025b.

20 AfDB 2025b.

21 ECA 2019.

22 IMF 2020.

23 AfDB 2025a.

24 World Bank 2025b.

25 OECD 2026.

26 ECA 2025a.

27 ECA 2025b.

28 Smit-Lengton 2025.

29 ECA 2025a.

30 World Bank 2025c.

31 World Bank 2025d.

32 Smit-Lengton 2025.

33 AfDB 2025a.

34 IMF 2025g, 2025j.

35 Esterhuysen 2025a; Farquhar 2025.

36 UNCTAD 2025b.

37 United Nations 2024.

38 AfDB 2025a.

39 Chuku and Yenice 2021.

40 AfDB 2025a.

41 African Peer Review Mechanism and ECA 2024, 2025.

42 Amaglobeli et al. 2025; World Bank 2020.

43 AfDB 2025a.

44 Mitchener and Trebesch 2022.

45 IMF 2025c.

46 IMF 2025e.

47 Benitez et al. 2023.

48 Econfin Agency 2025.

49 Bloomberg 2025.

50 World Bank 2019.

51 World Bank 2024.

52 Kenya Revenue Authority 2023, 2025.

53 Hakizimana and Santoro 2024; Rwanda Revenue Authority 2019.

54 South African Revenue Service 2023, 2024.

55 South African Revenue Service 2023.

56 South African Revenue Service 2023, 2024.

57 United Nations 2026.

58 United Nations 2026.

59 The Common Monetary Area is a monetary union in Southern Africa linking Eswatini, Lesotho, Namibia, and South Africa.

60 Reserve Bank of Zimbabwe 2025; Verster 2025a.

61 Verster 2025a.

62 Esterhuysen 2025b.

63 Bank of Uganda 2025.

64 National Bank of Rwanda 2025.

65 Central Bank of Egypt 2025b.

66 World Bank 2025b.

67 IMF 2025b.

68 Bank of Ghana 2025; Bank of Uganda 2025; Bank of Zambia 2025; Central Bank of Egypt 2025a; Central Bank of Kenya 2025a; Central Bank of Nigeria 2025; National Bank of Ethiopia 2025; Reserve Bank of Zimbabwe 2025.

69 Verster 2025a.

70 Morgan Stanley 2025.

71 United Nations 2026.

72 Central Bank of Kenya 2025b.

73 South African Reserve Bank 2025.

74 PwC 2025.

75 Reuters 2025b.

76 AfDB 2025b.

77 Barrdear and Kumhof 2016.

78 Abdullahi et al. 2024.

79 Filani et al. 2021.

80 World Bank 2025a.

81 IMF 2025a.

82 Ratha et al. 2024.

83 Remitscope 2025.

84 WFP 2025.

85 UNCTAD 2025a.

86 The $35 billion Ras El-Hekma Development Project in Egypt, backed by Abu Dhabi Developmental Holding and the Egyptian government, will transform Ras El-Hekma City with hospitals, schools, universities, residential areas, resorts, and public facilities. The government will retain a 35 per cent stake.

87 UNCTAD 2025a.

88 UNCTAD 2025a.

89 UNCTAD 2025a.

90 https://unctad.org/publication/global-investment-trends-monitor-no-49.

91 PAPSS 2025.

92 Raithatha and Storchi 2025.

93 MTN Group Limited 2025.

94 Safaricom PLC 2023.

95 OPHI and UNDP 2025.

96 Alkire et al 2025.

97 Monetary (income poverty) is assessed using the World Bank's international extreme poverty lines ($3 a day in 2021 purchasing power parity terms) (Lakner et al. 2025).

98 Donald et al. 2023.

99 Donald et al. 2023.

100 World Bank 2025e.

101 Cattaneo and Robinson 2020.

102 OECD et al. 2022; Seekings, forthcoming.

103 UN-Habitat 2022.

104 UN-Habitat 2024.

105 UN-Habitat 2024.

106 Working poverty refers to employed people who live in households that fall below an accepted poverty line, generally $2.15 (in purchasing power parity terms) a day ("Statistics on working poverty," ILO).

107 ECA 2024; ILO 2024.

108 ECA 2024; ILO 2024.

109 Guven and Karlen 2020.

110 ILO 2025.

111 ILO 2018a, 2022. The share of persons with disabilities working in the informal sector is 78 per cent in Botswana and 98 per cent in Benin. A new International Labour Organization database highlights the labour market challenges of persons with disabilities (2022).

112 ILO 2018a, 2022.

113 Guven and Karlen 2020.

114 ILO 2023.

115 ILO 2023.

116 The World Health Organization reports that 91 per cent of urban residents breathe polluted air, which can exacerbate mental health issues, particularly among vulnerable groups (WHO 2018).

117 Harman et al. 2022.

118 AfDB and ECA 2024; World Economic Forum 2025.

119 UNDP 2016.

120 Mayowa et al. 2025; OECD 2021.

121 Mayowa et al. 2025.

122 GSMA 2022.

123 Bahia et al. 2020.

124 Jarrahi 2021.

125 Jarrahi 2021.

126 Gillwald, Odufuwa, and Mothobi 2018.

127 FAO 2018.

128 FAO 2018.

129 Vookoti 2013.

130 Hassan, Unwin, and Gardezi 2018.

131 Gillwald and Partridge 2022.

132 International Institute for Democracy and Electoral Assistance 2024.

133 Gillwald and Partridge 2022.

134 Gender gap in internet usage based on data from ECA, based on data from International Telecommunication Union (2025b), "Individuals owning a mobile phone by gender."

135 International Telecommunication Union 2025b. The gender gap is calculated as [(Percentage of men owning – percentage of women owning)/percentage of men owning] * 100.

136 Burga et al. 2021; Stewart et al. 2021.

137 Mayowa et al. 2025.

138 World Bank 2025f.

139 Borrowman et al. 2025.

140 AfDB and ECA 2024.

141 GSMA 2025a; IMF 2024; Mayowa et al. 2025; Oula et al. 2016; Zottel 2021.

CHAPTER 2 TECHNOLOGY AND INNOVATION FOR AFRICA'S GROWTH

Africa's input-driven growth has some limitations for its long-term productivity. With rising debt, climate shocks, and demographic pressures, closing the productivity gap through technology and innovation is a critical path to resilient and sustainable growth. This chapter provides empirical evidence on the contribution of frontier-technology readiness to productivity and income growth in Africa through two complementary channels. The first is skills development, with short-run adjustment costs but rising gains in the medium term. The second is industrial activity, which is found to be the most consistent contributor over the study horizon. By contrast, deploying technology alone yields modest and short-lived gains, with R&D and finance weak or misaligned in many countries.

Enhancing sectoral productivity and growth requires differentiated strategies, as agriculture risks being left behind without climate-smart reforms, irrigation, and targeted finance. Manufacturing emerges as Africa's anchor for structural transformation through technology and innovation clusters and corridors, while services thrive on digitalization and finance. But with limited human capital to sustain growth, institutions and regional cooperation are decisive for technology and innovation to flourish. Stronger governance, regulation, and public procurement can consolidate technology gains, while the AfCFTA provides the scale to embed innovation in regional value chains. With most economies on the continent dependent on agriculture, frontier technologies and innovation need to be directed towards climate resilience—from precision agriculture to renewable energy—to ensure that Africa's transformation is inclusive and sustainable.

These findings imply that Africa's technology agenda is macro-critical not only for accelerating growth but for strengthening resilience. Policy emphasis should shift from "digital expansion" alone to ecosystem readiness, especially skills and productive capabilities, to convert technological diffusion into sustained productivity gains.

FRONTIER TECHNOLOGY, PRODUCTIVITY, AND GROWTH

Over the past three decades, Africa's economic growth has been input-driven, led primarily by labour force expansion and the intensive use of natural resources rather than sustained improvements in productivity. Although this growth model delivered episodic gains—often during commodity booms—it has failed to generate durable increases in productivity or support deep structural transformation. As a result, many African economies remain highly exposed to external shocks, including commodity price volatility, climate-related disruptions, and tightening global financial conditions. The persistence of low productivity growth has become one of the central constraints on Africa's long-term development trajectory.

This challenge is becoming increasingly binding. As demonstrated in chapter 1, rapid population growth and accelerating urbanization are expanding the labour supply faster than productive employment opportunities, while fiscal space is narrowing under rising debt burdens and mounting climate-related spending needs. In this context, growth strategies that rely predominantly on factor accumulation are no longer sufficient. Sustaining economic growth, creating decent jobs, and raising living standards will require a decisive shift to productivity-enhancing sources of growth. For African economies, closing the productivity gap is macro-critical.

Technology and innovation are widely recognised as central to productivity growth and long-term economic expansion. From Joseph Schumpeter's idea of *creative destruction*, which highlights the role of entrepreneurship in disrupting old models and generating new ones, to the contributions of endogenous growth theory, which places technological innovation at the heart of long-term expansion, economic thought has consistently emphasised the transformative power of innovation. Technological innovation introduces new technologies into production and consumption. It identifies emerging possibilities, mobilizes the necessary human and financial resources, and transforms ideas into useful products and processes. Because innovation is *endogenous*—responsive to changes in demand and supply—it remains a critical driver of productivity gains and higher living standards.[1] *Technology* refers to the stock of knowledge, methods, and tools that serve as inputs into production and growth.[2] And *innovation* encompasses both the process of applying and recombining these capabilities, and the outcomes of that process—new or significantly improved products, processes, and organizational methods.[3]

Frontier technologies—such as artificial intelligence, blockchain, biotechnology, drones, and robotics—are reshaping production processes and service delivery across agriculture, manufacturing, construction, healthcare, education, and services worldwide. For Africa, these technologies offer the potential to leapfrog traditional development pathways, raise efficiency, and support industrial upgrading.

The current wave of technological change—often described as the Fourth Industrial Revolution—has intensified the debate on the role of technology in productivity growth. Frontier technologies—such as artificial intelligence, blockchain, biotechnology, drones, and robotics—are reshaping production processes and service delivery across agriculture, manufacturing, construction, healthcare, education, and services worldwide. For Africa, these technologies offer the potential to leapfrog traditional development pathways, raise efficiency, and support industrial upgrading. Precision agriculture can increase yields while reducing input costs. Digital platforms can expand access to markets and finance. And

renewable energy technologies can extend electricity to underserved regions. As highlighted in chapters 1 and 3, these technologies, when effectively deployed, can generate large productivity gains and broader development benefits. But they also carry significant risks, including labour displacements, widening inequalities, and skills mismatches—particularly in economies with large informal sectors and limited absorptive capacity—underscoring that their impact is neither automatic nor uniform.

Global experience shows that frontier technologies can boost productivity, stimulate entrepreneurship, and generate new employment opportunities, particularly in economies that have integrated them into production systems at scale. North America, Europe, and parts of Asia have emerged as leaders in artificial intelligence, robotics, and advanced manufacturing. By contrast, Africa continues to lag behind. Despite the rapid diffusion of basic digital technologies—especially mobile connectivity—productivity gains across the continent have remained modest, uneven, and often short-lived. Even among Africa's frontrunners, such as Egypt, Kenya, Rwanda, and South Africa, progress in frontier technologies remains limited relative to emerging economies such as Brazil, India, and Saudi Arabia.

Evidence increasingly indicates that technology adoption alone is insufficient to generate sustained productivity growth. The economic impact of frontier technologies depends on complementary capabilities for technologies to be absorbed, adapted, and scaled. Skills, industrial capacity, digital and physical infrastructure, institutional quality, and access to finance jointly shape whether technological advances translate into economy-wide productivity gains. Weaknesses along any of these dimensions can blunt innovation's impact, resulting in shallow or temporary growth effects rather than durable structural transformation.

Against this backdrop, the chapter examines the empirical relationship between frontier technology, productivity, and growth in African economies. It addresses three interrelated questions. First, to what extent is frontier technology and innovation associated with higher productivity outcomes in Africa? Second, how does economic growth respond to frontier technology and innovation across countries? Third, which underlying dimensions—such as skills, digital infrastructure, industrial activity, and access to finance—are most closely associated with productivity and growth outcomes in Africa?

Even among Africa's frontrunners, such as Egypt, Kenya, Rwanda, and South Africa, progress in frontier technologies remains limited relative to emerging economies such as Brazil, India, and Saudi Arabia.

These questions are not fully resolved in the empirical literature. Much of the evidence on innovation and growth in developing economies relies on narrow innovation input measures, such as R&D expenditure or patent counts, and estimates their direct association with growth. While such approaches often yield weak or inconsistent results for Africa, they do not distinguish between the limited innovation effort and the constraints in translating innovation into productivity gains under weak enabling conditions. In addition, many studies examine technology adoption and growth without explicitly analysing productivity outcomes alongside growth, making it difficult to assess how efficiency outcomes and growth performance are jointly associated with technology adoption over time.

The empirical approach in this chapter addresses these limitations. By combining a multidimensional measure of frontier technology readiness with explicit modelling of total factor productivity, the analysis allows for a clearer identification of how technological readiness translates into efficiency gains and, subsequently, into economic growth. The use of the Frontier Technology Readiness Index (FTRI)[4] is particularly appropriate in the African context, as it captures not only innovation inputs but also the complementary conditions—skills, infrastructure, finance, and industrial activity—that shape the productivity impact of frontier technologies. This framework therefore moves beyond asking whether innovation matters, to identifying the conditions under which it becomes a sustained driver of productivity-led growth in Africa.

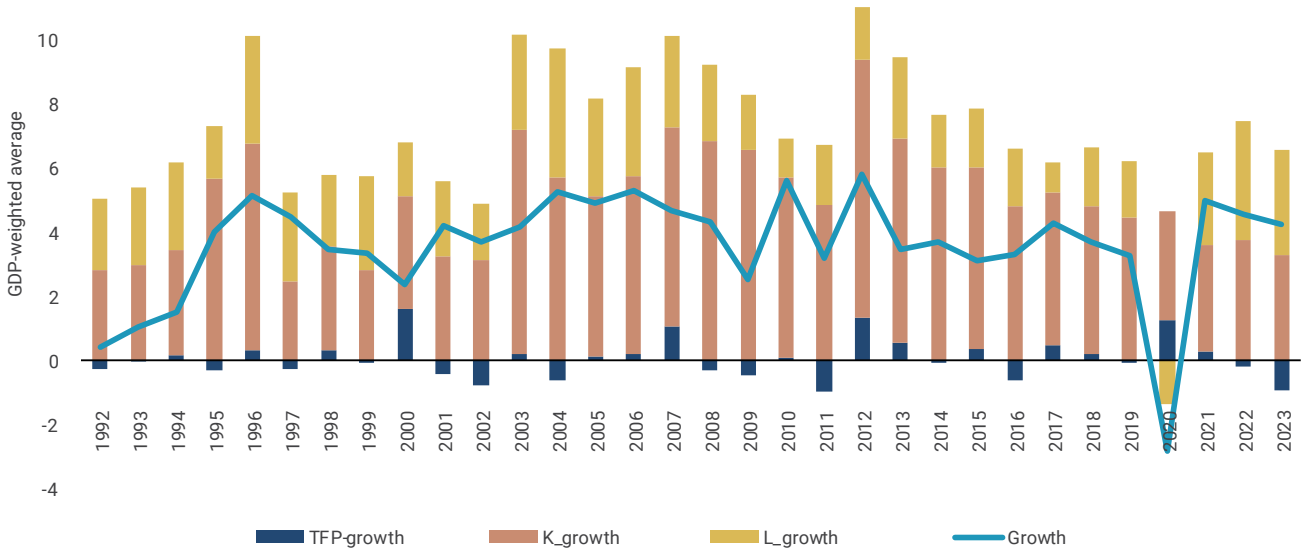
GROWTH AND PATTERNS OF TECHNOLOGY AND INNOVATION IN AFRICA

Between 2000 and 2023, Africa experienced steady economic growth, often exceeding global averages. However, this growth was driven largely by factor accumulation—labour expansion supported by demographic growth and capital deepening in infrastructure, extractive industries, and construction—rather than by efficiency gains. Total factor productivity (TFP) made a negative contribution over this period, pointing to weak improvements in the effective use of labour and capital (figure 2.1).

This input-driven growth model raises sustainability concerns. As noted in chapter 1, rising public debt in many countries limits the scope for continued capital accumulation without productivity gains. At the same time, rapid labour-force growth can support long-term development only if accompanied by job creation, skills development, and technological progress. Without a shift to productivity-enhancing sources of growth, Africa risks diminishing returns, heightened fiscal pressures, and stalled structural transformation.

Between 2000 and 2023, Africa experienced steady economic growth, often exceeding global averages. However, this growth was driven largely by factor accumulation—labour expansion supported by demographic growth and capital deepening in infrastructure, extractive industries, and construction—rather than by efficiency gains.

Figure 2.1 Sources of growth in Africa, 2000–23



Source: ECA calculations based on Penn World Table, WDI, and ILO, 2025.

In this respect, Africa's trajectory differs from that of emerging Asian economies, where rapid industrial upgrading, export diversification, and integration into global value chains have sustained stronger TFP growth since 2000. Advanced economies also illustrate how long-term growth depends primarily on productivity, as both labour and capital expansion are relatively constrained.[5]

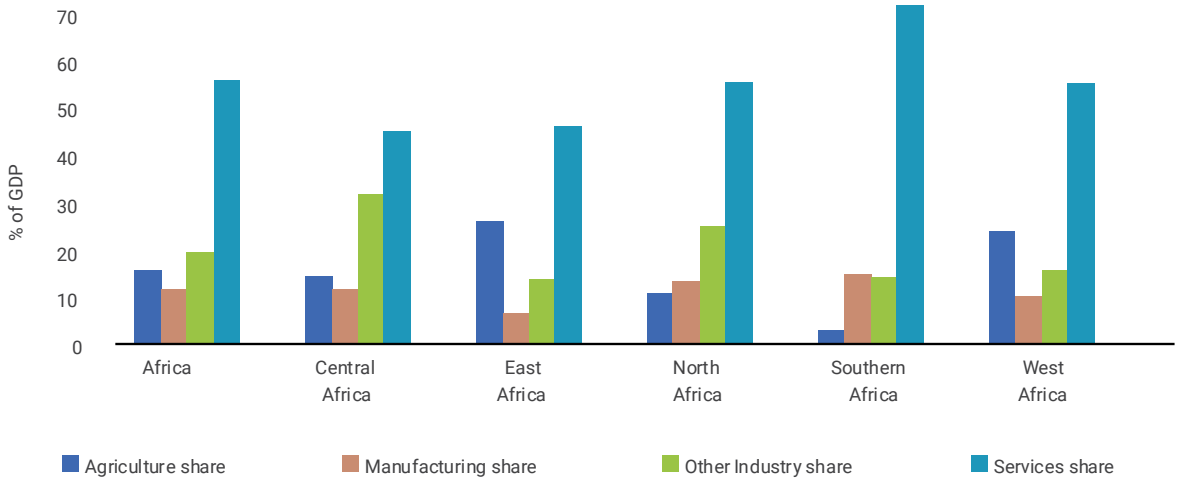
STRUCTURAL TRANSFORMATION REMAINS LIMITED

In addition, the continent's consistent economic growth over the past 20 years has failed to translate into robust structural transformation. As observed in chapter 1, services account for a larger share of GDP, yet agriculture continues to employ a high share of the workforce. Manufacturing has seen pockets of productivity improvement, but these gains have been uneven across countries and sectors.

The share of manufacturing in GDP, slightly above 13 per cent in 2000, dropped to about 10–11 per cent by the mid-2010s and stagnated around that level through 2023.

The reallocation of labour and capital from low-productivity activities—such as subsistence farming to higher-productivity manufacturing and modern services—has been slow in Africa. Unlike East Asia, where industrialization drove rapid and sustained growth, the continent's manufacturing has stagnated. The share of manufacturing in GDP, slightly above 13 per cent in 2000, dropped to about 10–11 per cent by the mid-2010s and stagnated around that level through 2023 (figure 2.2). This trajectory contrasts with East Asia's manufacturing boom and underscores the continent's premature deindustrialization—a shift into services, often dominated by low-productivity activities, at relatively low levels of income.[6]

Figure 2.2 Average sectoral shares of value added, 2000–24



Source: ECA calculations based on WDI and ILO, 2025.

At a subregional level, North and Southern Africa maintained higher manufacturing shares, reflecting more diversified economies, while West, East, and Central Africa displayed lower and more volatile shares, showing clear declines since the early 2000s. The common trend across all subregions is of stagnation since the late 2000s, underscoring the persistence of slow and uneven structural transformation.

Some countries, such as Morocco and Ethiopia, built notable industrial bases, while others, like Kenya, developed hubs in ICT and services. Yet in general, Africa's economic complexity remains low, and exports

are still heavily concentrated in commodities and low value products.[7] This lack of diversification both constrains income growth and increases vulnerability to external shocks.

With limited structural transformation and without stronger productivity gains, growth based on expanding capital and labour will face diminishing returns. Raising TFP will require improvements in allocative efficiency, better functioning markets, and stronger competition to raise returns on investment. Innovation and technology adoption will be central to this shift. Strengthening human capital, crowding in private investment, and supporting innovative ecosystems will help sustain growth and create more resilient economies.[8]

Technology and innovation are widely recognized as key drivers of productivity growth, structural transformation, and long-term development, not only through frontier invention but through effective adoption, diffusion, and scaling within domestic production systems. In Africa, however, the development impact of technological change has remained limited. Despite rapid diffusion of basic digital technologies, productivity gains have been modest and uneven, reflecting fragmented adoption and weak integration into productive activities. These outcomes point to persistent constraints in innovation ecosystems—particularly in skills, infrastructure, finance, and institutional capacity—limiting the ability of firms and economies to translate technology into sustained development gains. These structural challenges are reflected in widely used measures of technological and innovation performance.

Despite rapid diffusion of basic digital technologies, productivity gains have been modest and uneven, reflecting fragmented adoption and weak integration into productive activities.

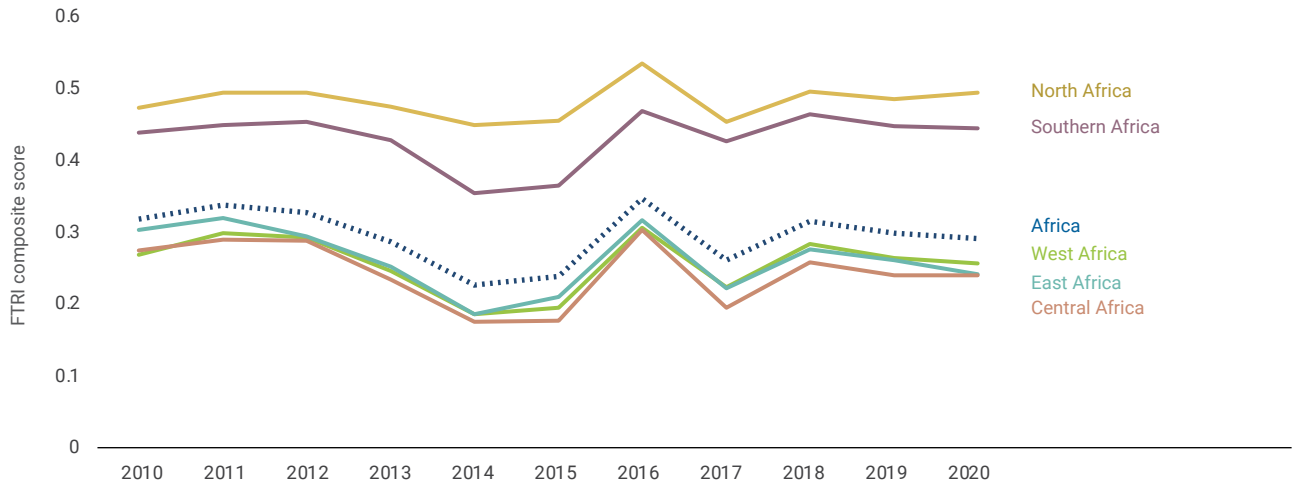
PATTERNS OF INNOVATION, TECHNOLOGY ADOPTION, AND POTENTIAL IMPACT ON DEVELOPMENT IN AFRICA

Based on technology and innovation measures such as the UNCTAD's FTRI and the Global Innovation Index (GII)[9] of World Intellectual Property Organization (WIPO), African economies consistently score below global averages, closely aligned with income levels.[10] This reflects underdeveloped innovation systems, and weak diffusion of new technologies.

Between 2010 and 2023, Africa's FTRI showed a modest upward trend for the continent as a whole, rising from just above 0.30 in 2010 to around 0.29–0.30 by 2020, with notable cyclical fluctuations rather than sustained acceleration was realised. This pattern points to incremental capability formation, punctuated by temporary setbacks, rather than a decisive structural shift in technological readiness (figure 2.3). Subregional averages reveal persistent and widening disparities. North Africa consistently leads, with composite scores averaging close to 0.48–0.50, reflecting stronger ICT infrastructure, skills formation, and industrial capabilities. Southern Africa follows, with scores around 0.44–0.46, benefiting from more diversified economies and stronger firm-level capabilities, though without a clear upward break. By contrast, West, East, and Central Africa cluster at significantly lower levels, with average scores mostly between 0.22 and 0.30, indicating weaker diffusion of frontier technologies and more limited absorptive capacity. Central Africa remains the lowest-performing subregion throughout the period, underscoring deep structural constraints related to infrastructure gaps, skills shortages, and limited industrial activity.

Across all subregions, progress has stalled since the mid-2010s, reinforcing the conclusion that Africa's technological upgrading remains slow and uneven, and insufficient to underpin broad-based productivity-led growth without stronger, coordinated policy action.

Figure 2.3 Technology and innovation development (FTRI composite, average) by subregion, 2010–23



Source: ECA calculations based on UNCTAD's Frontier Technology Readiness Index (FTRI), 2025.

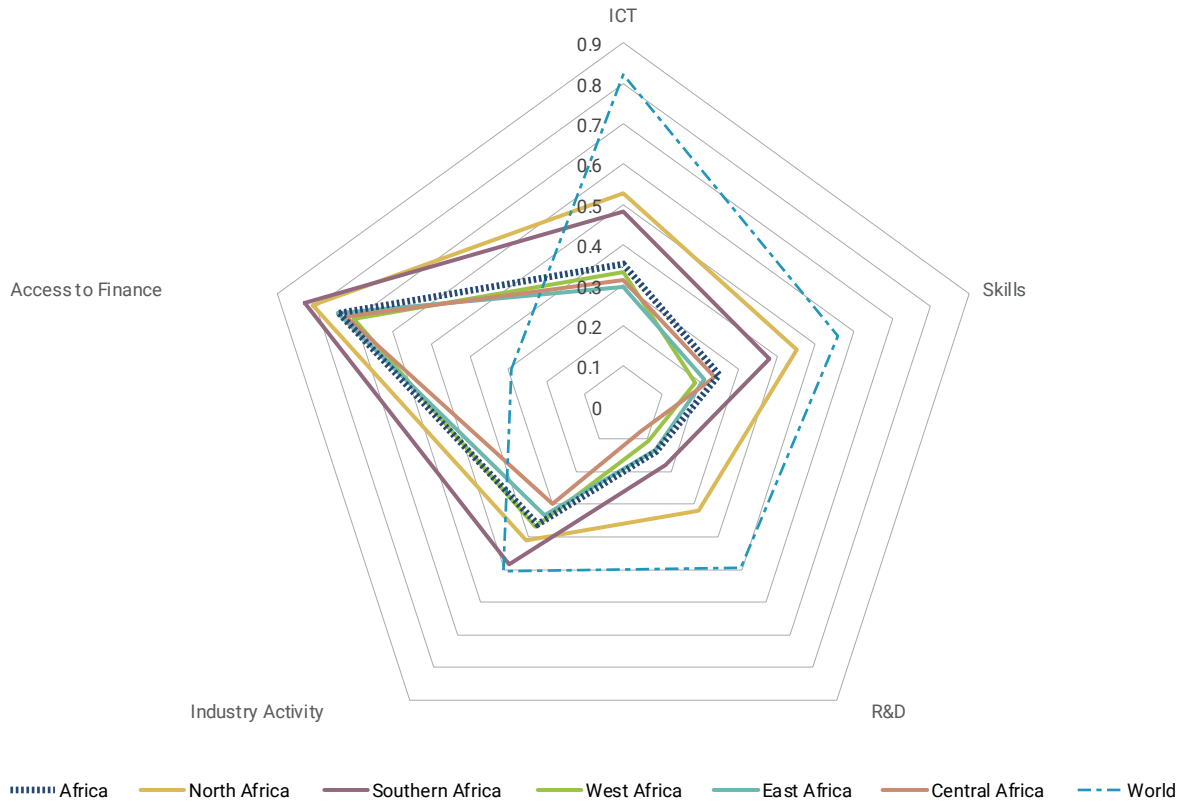
Inadequate progress in technology and innovation

Comparing Africa's subregional medians with the continental benchmarks highlights the structural weaknesses that continue to limit the continent's technology and innovation progress (figure 2.4). Within the Frontier Technology Readiness Index, access to finance emerges as Africa's strongest-performing pillar, driven by innovations in mobile money and fintech, particularly in West and East Africa, which have significantly improved households' and firms' ability to transact and access short-term financial services. But this does not imply adequate financing for development or innovation. Within the FTRI framework, access to finance mainly reflects financial inclusion and the expansion of digital financial services, rather than the provision of long-term financing suited to productive and innovative investment.

Benchmarking against global averages reveals that Africa still underperforms in access to finance relative to the world frontier. The world benchmark displays high and well-aligned performance across ICT, skills, R&D, industry activity, and finance. Rather than any single pillar standing out, these elements reinforce one another: skills support technology adoption, R&D feeds into firms, industry activity absorbs innovation, and finance underpins productive investment. This balanced configuration illustrates how innovation systems function in practice: productivity gains emerge not from the expansion of any single pillar, but from their coherent interaction. Finance amplifies the effects of skills, R&D, and industrial capacity. R&D is embedded in firms and value chains, and technology adoption is supported by both human capital and market demand. This systemic coherence—rather than high performance in any individual dimension—underpins sustained productivity growth. For this reason, the world benchmark is not simply "higher" than Africa's profile, but qualitatively different, representing a more integrated and mutually reinforcing innovation ecosystem.

At the subregional levels, North and Southern Africa are better positioned, supported by stronger financial systems and more diversified economies, yet they also fall short of global norms. By contrast, performance across the remaining subpillars remains weak and uneven. ICT infrastructure shows moderate development, with North and Southern Africa performing better, reflecting higher connectivity, digital adoption, and more established infrastructure bases. Skills and industry activity display similarly modest levels across most subregions, indicating persistent gaps in human capital formation, firm-level capabilities, and productive diversification. While North Africa appears comparatively better positioned across several dimensions, and Southern Africa shows stronger industry activity, both remain constrained by structural weaknesses that limit the scaling and diffusion of innovation.

Figure 2.4 Technology and innovation average subpillars, 2023



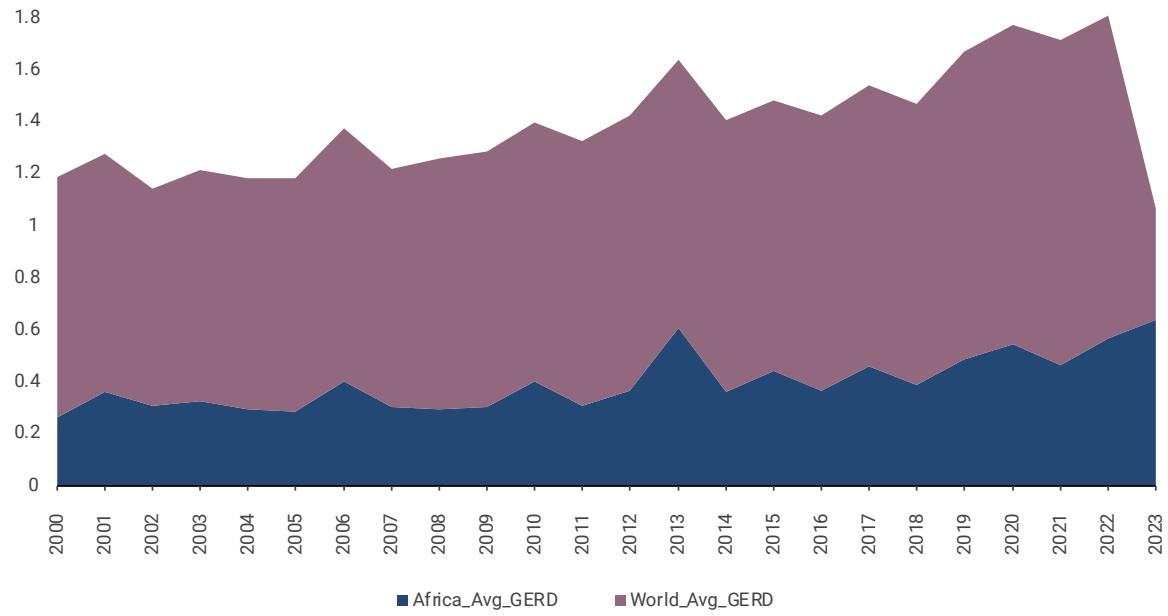
Source: ECA calculations based on UNCTAD's FTRI, 2025.

Comparing Africa's subregional medians with the continental benchmarks highlights the structural weaknesses that continue to limit the continent's technology and innovation progress.

The most pronounced and systemic deficit lies in research and development (R&D). All African subregions record very low R&D scores, underscoring the continent's limited capacity to generate, adapt, and diffuse new knowledge. This pattern is consistent with expenditure data. Between 2000 and 2023, African countries invested on average only about 0.45 per cent of GDP in R&D, compared with a global average of around 1.7 per cent, making Africa the lowest-spending region worldwide (figure 2.5). No African country had reached the African Union's target of 1 per cent of GDP in R&D by 2021.[11] Even the continent's top performers remain well below the global average and far behind innovation leaders such as Israel, Japan, and South Korea, where R&D spending typically ranges between 3 and 4 per cent of GDP.[12]

In many low-income African countries, R&D spending remains below 0.2 per cent of GDP, reflecting deep structural financing and institutional gaps in science, technology, and innovation systems. This chronic underinvestment is closely associated with weak scientific and technological outputs. Despite accounting for around 17 per cent of the world's population, Africa produces only 1–2 per cent of global research publications and patents.[13] According to WIPO, less than 1 per cent of global patent applications originate from African inventors.[14]

Figure 2.5 Gross domestic expenditure on R&D



Source: ECA calculations based on World Bank (2023) and World Economic Forum (2023).

A central message: Africa's innovation challenge is not primarily one of basic financial access, but of insufficient depth, quality, and direction of investment into skills, industry, and especially R&D. The resulting innovation deficit constrains productivity growth, reinforces dependence on low-value primary activities, limits the adoption and adaptation of emerging technologies, and curtails the creation of high-skilled employment—imposing significant long-term economic and developmental costs.

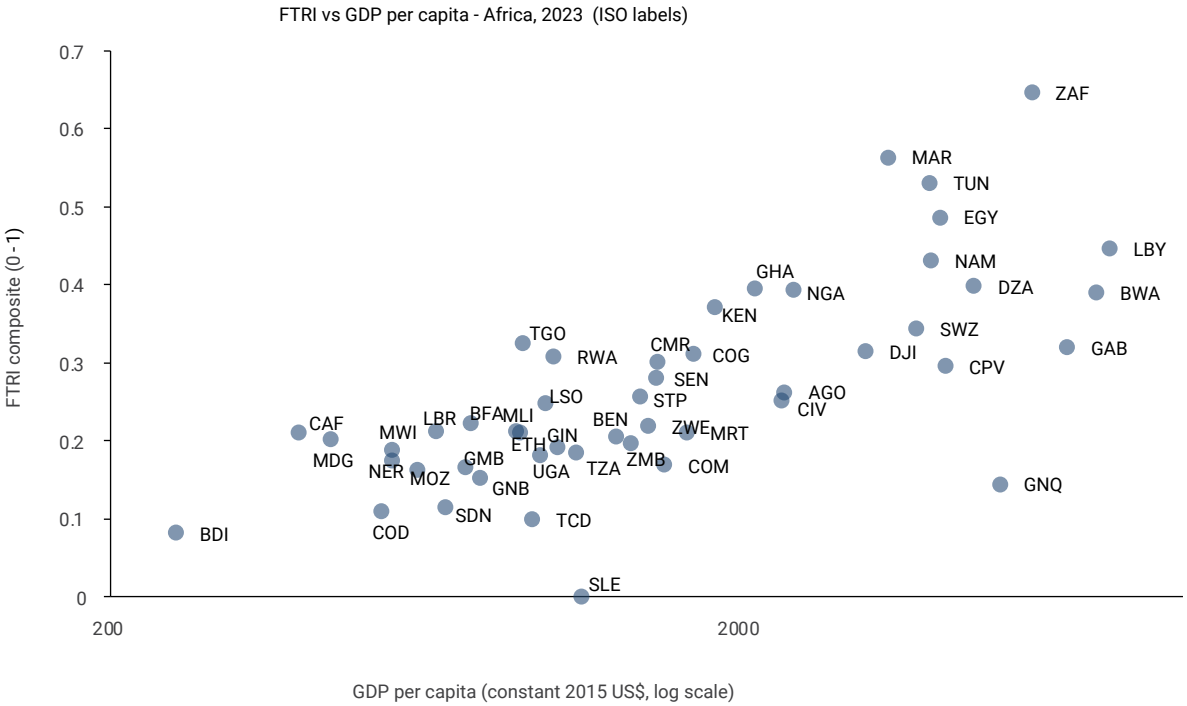
However, a few countries have made steady gains, demonstrating higher and more consistent R&D spending. Policy frameworks, such as the AU's 1 per cent target and the creation of national science and innovation funding initiatives, are gradually raising visibility and political commitment. At the same time, Africa's emerging sectors—from renewable energy to fintech and digital technologies—are drawing in private R&D investment. Moreover, international partnerships, such as AfDB initiatives and UN-supported STI programmes, are helping to catalyse research activities.

The correlation between GDP per capita, and technology and innovation captured by FTRI across African countries is positive (figure 2.6). Higher-income economies such as Egypt, Mauritius,

African countries invested on average only about 0.45 per cent of GDP in R&D, compared with a global average of around 1.7 per cent, making Africa the lowest-spending region worldwide.

Morocco, South Africa, and Tunisia record higher FTRI scores, reflecting stronger performance in areas such as ICT penetration, human capital development, and innovation systems. By contrast, low-income economies such as Burundi, Central African Republic, and Chad cluster at the bottom, with both low GDP per capita and weak technology related investments. Some outliers are notable. Resource-rich economies such as Equatorial Guinea display relatively high GDP per capita but weak technology and innovation performance, underscoring that resource rents do not automatically translate into advances in technological and innovation systems. This suggests that income alone is not sufficient; policy choices and investment in enabling ecosystems matter greatly.

Figure 2.6 Technology and innovation and GDP per capita in Africa, 2023



Source: ECA calculations based on UNCTAD's Frontier Technology Readiness Index (FTRI), 2025.

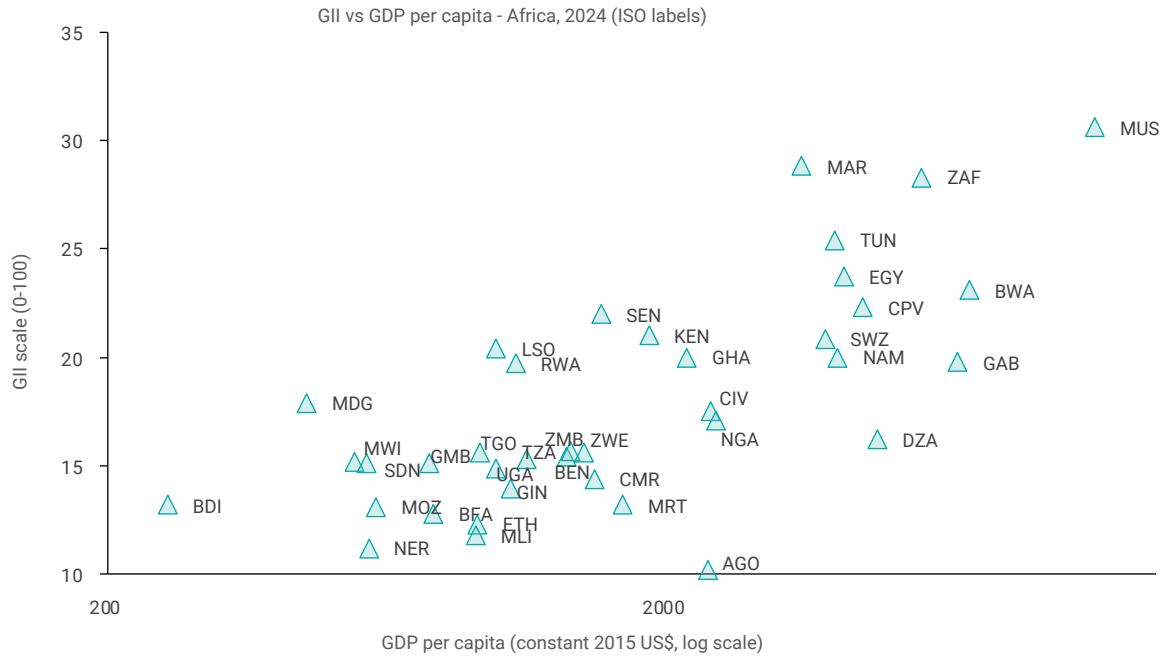
Diverging trajectories

Overall, Africa's technology divide mirrors its income divide, but countries can diverge from the expected pattern depending on whether they implement deliberate strategies to build innovation capacity. This makes a strong case for targeted policies in ICT, skills development, and innovation ecosystems as critical levers to enhance technology and innovation and ensure that income growth is accompanied by technological upgrading.

The correlation between GDP per capita, and technology and innovation captured by FTRI across African countries is positive.

Some internal divides also mirror income inequalities as well as urban rural inequalities. Many African economies demonstrate performance levels that exceed expectations relative to their incomes that are overperforming, performing in line with, or underperforming their level of development (figure 2.7). Some economies stand out as consistent innovation overperformers. Rwanda has maintained above-expected performance since 2012, establishing itself as one of the continent's most persistent good performers. Madagascar has shown steady and sustained progress since 2016, while Senegal and Morocco have also recorded notable gains, positioning themselves as emerging innovation hubs in West and North Africa. South Africa has displayed strong results since 2018, while Burundi has recently registered significant improvements, reflecting its gradual but meaningful progress in innovation capacity.

Figure 2.7 GDP per capita and innovation performance in Africa, 2024



Source: ECA calculations based on WIPO data, 2025.

Several other African economies perform broadly in line with expectations given their level of development. These include Cabo Verde, Egypt, Ghana, Kenya, Mozambique, Mauritius, Nigeria, Togo, Tunisia, the United Republic of Tanzania, Uganda, Zambia, and Zimbabwe. Their performance illustrates steady alignment between innovation outcomes and economic fundamentals, even if they do not consistently exceed expectations.

Africa's ambition to climb the innovation ladder is increasingly reflected in the growth of science and technology (S&T) clusters. Since 2016, the Global Innovation Index (GII) has identified clusters worldwide using two indicators: the location of inventors in WIPO Patent Cooperation Treaty applications and the authorship of scientific publications.[15] For the first time in 2024, Cairo entered the world's top 100 S&T clusters, marking Africa's debut in this global ranking. Beyond Cairo, the GII identified the continent's top 50 clusters. Johannesburg/Pretoria and Cape Town (South Africa), Tunis (Tunisia), and Alexandria (Egypt) followed Cairo at the top of the African ranking. Egypt leads with 11 clusters, followed by South Africa (8), Morocco (5), Nigeria and Tunisia (4 each), Ethiopia and Ghana (2 each), and Kenya (1). These hubs are largely driven by scientific publications rather than patenting, underscoring their role as science rather than full innovation clusters.

Many African economies demonstrate performance levels that exceed expectations relative to their incomes that are overperforming, performing in line with, or underperforming their level of development.

Although Africa's overall technology and innovation activity remains limited, there are promising signs of emerging ecosystems. Kenya, Nigeria, and South Africa have developed vibrant start-up scenes and technology hubs, while Africa's contribution to global scientific publications—still modest—has grown in recent years.[16] Scaling up these gains will require closing the continent's R&D investment gap, strengthening universities and research institutions, and improving intellectual property protection.[17] Building skills and infrastructure is equally critical for firms to move up value chains and boost productivity.

Some countries are already diversifying their economic structures. Morocco and Ethiopia have created pockets of industrial capacity, while Kenya has positioned itself as a regional hub for ICT services. These cases illustrate the potential for innovation and industrialization, yet they remain exceptions in a context where economic complexity is low, and exports remain largely commodity-based.

Looking ahead, the challenge is to accelerate this gradual progress to avoid exclusion from emerging global production networks in fields such as AI, green hydrogen, biotechnology, and the wider Fourth Industrial Revolution. Progress in finance, ICT diffusion, and regional policy initiatives provides a foundation, but ensuring that all subregions advance together will be essential. Without greater integration to harmonize standards, pool research capacity, and finance digital and green transitions collectively, Africa risks diverging trajectories with more advanced regions pulling ahead as others fall farther behind.

In this context, Africa's effective readiness for frontier technologies depends on strengthening its capacities to produce, absorb, and consume them in a coordinated manner. Production requires greater investment in R&D, stronger links between research institutions and firms, and supportive industrial and innovation policies. Absorption hinges on reliable digital and energy infrastructure, improved access to finance and sustained skills development to enable firms—especially SMEs—to adopt new technologies at scale. Consumption, in turn, depends on affordable connectivity, digital inclusion, and robust regulatory frameworks that ensure broad access and fair competition. Aligning and deepening these three dimensions is essential for frontier technologies to drive structural transformation and inclusive growth rather than widen regional and social divides.

Africa's effective readiness for frontier technologies depends on strengthening its capacities to produce, absorb, and consume them in a coordinated manner. Production requires greater investment in R&D, stronger links between research institutions and firms, and supportive industrial and innovation policies.

INNOVATION AND ECONOMIC GROWTH: THEORETICAL AND EMPIRICAL PERSPECTIVES

INNOVATION AS THE ENGINE FOR GROWTH

Innovation is widely recognized as the engine for long-term growth, but the mechanisms that drive its development remain contested. The literature broadly clusters into three strands: innovation as an exogenous driver, innovation as an endogenous process, and innovation as conditioned by human capital and institutions. For Africa's development, these distinctions are not merely theoretical, they shape whether innovation policy should prioritize frontier technologies R&D, technologies adoption, institutional reform, or capability-building. The relevance of each strand depends on Africa's structural characteristics, including late industrialization, small domestic markets, and limited research intensity.

In the neoclassical framework, Solow (1956) treated technological progress as the ultimate source of sustained growth but exogenous to the model. His approach confirmed that "capital accumulation alone is insufficient" but offered little guidance on how innovation arises.

While influential, this framework offers limited policy traction for African economies, where innovation is less about autonomous technological breakthroughs and more about diffusion, adaptation, and learning.

By contrast, Schumpeter (1934) described growth as a process of "creative destruction," where entrepreneurial innovations transform markets and production systems. He identified five types of innovation—products, processes, markets, supply sources, and organization. And he stressed competition and entrepreneurial ecosystems, though without fully addressing social or institutional dimensions. Schumpeterian insights resonate with African contexts characterized by rapid firm entry, informal entrepreneurship, and sectoral reallocation, but they require institutional mediation to avoid reinforcing market concentration or informality rather than productive transformation.

Endogenous growth theory from the late 1980s incorporated innovation directly into models. Romer (1989) viewed technological change as the outcome of deliberate investments in human capital and R&D, generating spillovers that justify public intervention through subsidies, tax incentives, and intellectual property rights. Aghion and Howitt (1990) formalized Schumpeterian dynamics, showing how successive waves of innovation drive growth but also create "business-stealing" effects that can discourage further investment if monopoly power becomes entrenched. For Africa, endogenous models highlight both opportunities and constraints: while spillovers justify public support, limited fiscal space and weak competition policy can mute their effectiveness or exacerbate inequality.

Complementary perspectives highlight enabling conditions. Lucas (1988) emphasized human capital accumulation as a foundation for innovation, while North (1990) and Acemoglu, Johnson, and Robinson (2005) underscored the centrality of institutions. Secure property rights, effective governance, and rule of law create incentives for innovation and technology adoption, while extractive institutions undermine them. This strand is particularly salient for Africa, where institutional quality and skill gaps can determine whether innovation manifests as productivity-enhancing transformation or remains confined to isolated enclaves.

INNOVATION DOES NOT AUTOMATICALLY TRANSLATE TO GROWTH

Empirical research consistently identifies innovation as an important driver of economic growth, though the magnitude and channels of this relationship vary significantly across contexts. At the global level, innovation inputs—commonly proxied by research and development (R&D) expenditure and patent activity—are positively associated with income growth, with the strongest effects in advanced economies.

In these settings, skilled labour, effective institutions, and large domestic markets enhance the capacity to absorb and deploy new technologies, allowing innovation to translate more readily into productivity gains.[18] More recent contributions emphasize that these outcomes depend critically on the presence of enabling innovation ecosystems, highlighting the central role of education, governance, infrastructure, and institutional quality in converting innovation inputs into sustained economic performance.[19] Taken together, this literature suggests that innovation or technology indicators in isolation are insufficient; what matters is the broader system that generates, diffuses, and applies innovation.

The innovation–growth relationship is also dynamic and bidirectional. Innovation contributes to economic growth, while growth itself generates the resources required for further investment in innovative activities, creating a reinforcing feedback loop.[20] Within this dynamic process, the quality of innovation has been shown to be decisive. High-impact patents exert a stronger and more persistent effect on long-term growth than simple patent counts, which often capture incremental or low-value innovations.[21] This distinction is particularly relevant for developing regions, where conventional innovation metrics may overstate innovative effort while understating its developmental and productivity impact.

For developing and transition economies, empirical evidence is more heterogeneous, reflecting differences in institutional capacity, industrial structure, and market depth. Some studies identify a reinforcing cycle between innovation and growth, but only under favourable institutional conditions.[22] In other contexts, innovation follows rather than precedes growth, suggesting that technological upgrading may be an outcome of structural transformation rather than its initial driver, particularly where industrial bases are shallow and institutions are weak.[23] Country evidence reinforces this conditionality. In India, innovation's contribution to growth diminished as expansion became increasingly driven by labour force growth and other nontechnological factors.[24] In contrast, in several Asian economies, innovation has contributed to growth through specific channels—most notably financial innovation and integration into global technology networks—rather than through domestic R&D alone.[25] These experiences suggest that for latecomer economies such as African countries,

For Africa in particular, innovation policy must be embedded within broader ecosystem reforms that strengthen governance and the quality of institutions, expand education and skills, improve infrastructure, and connect domestic firms to global knowledge flows.

connectivity to global knowledge and production systems may be more consequential than attempts to replicate advanced-economy R&D models.

The evidence from Africa points to similar, and often more binding, conditionalities. Innovation contributes positively to growth when supported by adequate human capital accumulation and investment, and when institutional quality exceeds a minimum threshold.[26] At the same time, Africa's innovation systems remain heavily dependent on external sources, including foreign patents and imported R&D, reflecting limited domestic capacity to internalize innovation gains.[27] This structural dependence constrains the translation of innovation inputs into sustained productivity improvements. Firm-level evidence further highlights the role of complementary constraints. Innovation-led job creation is frequently undermined by infrastructure bottlenecks, especially unreliable electricity supply. And weak institutional environments can dampen or even reverse the growth impacts of otherwise promising innovations.[28] Financial innovations such as mobile money have generated positive growth and inclusion effects in several African countries, but their broader impact remains contingent on institutional and regulatory quality.[29]

Overall, the literature converges on a central insight: innovation does not automatically translate into economic growth. Its effectiveness depends on the interaction between innovation inputs and the quality of institutions, human capital, infrastructure, and absorptive capacity. For Africa in particular, innovation policy must be embedded within broader

ecosystem reforms that strengthen governance and the quality of institutions, expand education and skills, improve infrastructure, and connect domestic firms to global knowledge flows. Under these conditions, innovation can evolve from fragmented and isolated initiatives into a sustained driver of productivity-led and inclusive growth.

For African policymakers, the implication is clear: innovation strategies should be assessed not by their technological ambition alone, but by their alignment with structural transformation objectives, employment creation, and institutional readiness.

For African policymakers, the implication is clear: innovation strategies should be assessed not by their technological ambition alone, but by their alignment with structural transformation objectives, employment creation, and institutional readiness.

TRANSFORMATIVE POTENTIAL OF FRONTIER TECHNOLOGIES FOR ECONOMIC GROWTH

Building on the theoretical and empirical foundations just discussed, recent global evidence highlights the transformative potential of frontier technologies for developing countries. Advances in artificial intelligence (AI), the Internet of Things (IoT), drones, and renewable energy technologies are increasingly seen as general-purpose technologies that can accelerate catch-up with advanced economies.[30] For instance, AI and IoT enable real-time data collection, monitoring, and communication across sectors; drones have improved agricultural productivity through precision crop monitoring, enhanced logistics and service delivery, and strengthened emergency response capabilities; and solar photovoltaic technologies have become central to renewable energy adoption and sustainable development pathways.[31]

Frontier technologies generally have a positive, though context-dependent, impact on economic growth. Ofori et al. (2025) report a modest but statistically significant growth effect associated with frontier technology adoption. A growing body of literature further identifies specific transmission channels for these technologies to influence growth, with financial inclusion emerging as one of the most robust. In Africa, mobile phone penetration, internet connectivity, and mobile money adoption significantly expand access to financial services, particularly among underserved populations.[32] This channel is especially salient where persistent financial exclusion has historically constrained firm expansion and household investment, reinforcing the finance-led growth mechanism.

Beyond finance, frontier technologies also support structural transformation and productivity-enhancing sectoral shifts. Digital adoption lowers entry barriers, supports entrepreneurship, and facilitates the reallocation of labour from low- to higher-productivity activities. Internet expansion accelerates labour reallocation towards more productive sectors in Africa, while entrepreneurship combined with digital adoption fosters broader economic development.[33] These findings underscore the catalytic role of technology in enabling structural change rather than merely raising output within existing sectors.

A closely related strand of the literature focuses on digital infrastructure as a foundational input to growth. Broadband subscriptions, mobile cellular adoption, and related digital investments are positively associated with GDP per capita across African economies.[34] Digital infrastructure can thus function as a general-purpose input that enables productivity gains across multiple sectors, rather than as a sector-specific intervention. Importantly, studies employing econometric approaches that address endogeneity and simultaneity—such as instrumental variable and dynamic panel estimators—continue to find positive or causal effects, indicating that the observed relationships are not driven by reverse causality.[35] The consistency of these findings across African subregions and their replication in global studies strengthen their external validity.[36]

Evidence from other developing regions reinforces these conclusions. In Asia and Latin America, positive growth effects are associated with technology

adoption, digital infrastructure expansion, and connectivity to global production and knowledge networks.[37] So, the growth benefits of frontier technologies are not region-specific but depend on broader enabling conditions.

But the positive effects of frontier technologies are not universal. Limited state capacity, weak physical infrastructure, governance failures, and persistent digital divides can blunt—or even reverse—the growth benefits of frontier technologies adoption.[38] These countervailing findings caution against techno-optimism and reinforce the importance of complementary reforms.

Overall, the evidence indicates that frontier technologies can be transformative for Africa only when embedded in broader development strategies that address institutional quality, infrastructure gaps, human capital constraints, and distributional concerns. Technology–growth analysis must therefore be situated within wider sociopolitical and institutional contexts, particularly in developing regions. Under such conditions, frontier technologies can move beyond isolated applications to become sustained drivers of productivity, structural transformation, and inclusive growth.

TOWARDS A CONCEPTUAL FRAMEWORK FOR INNOVATION-LED GROWTH

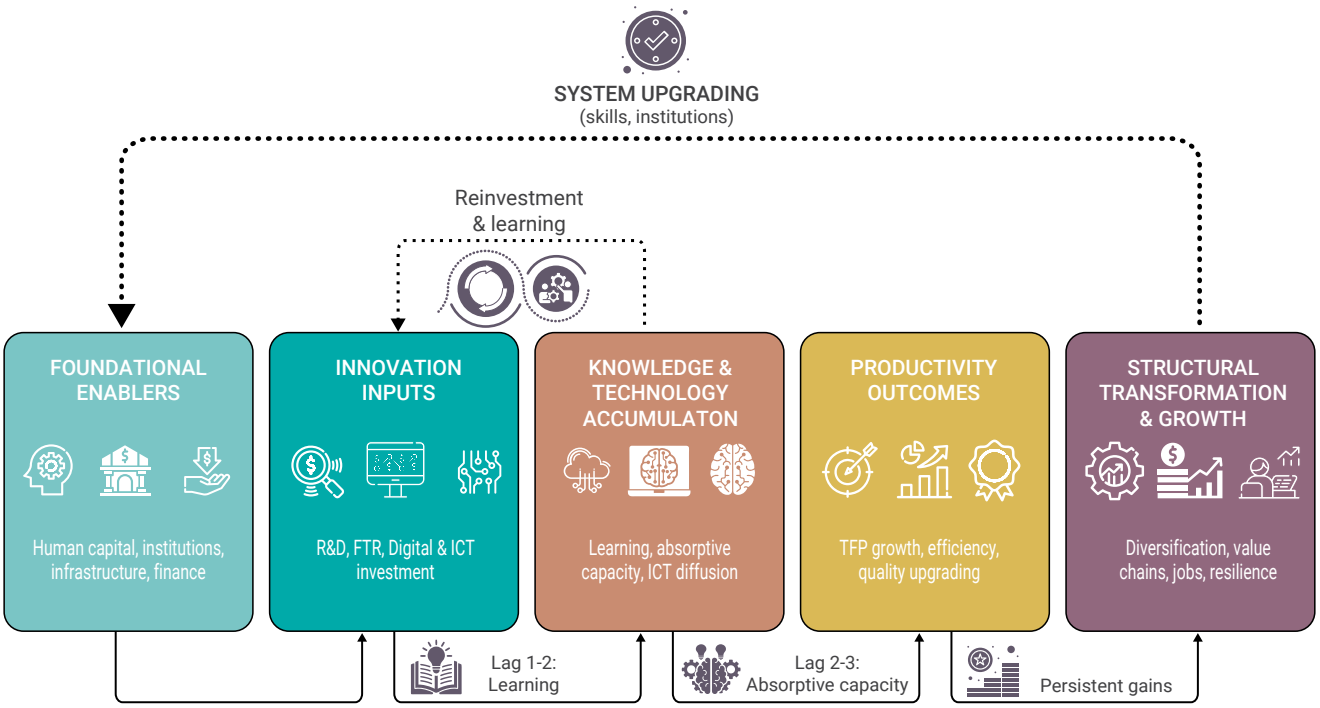
Much of the growth and innovation literature treats innovation or technology as a single, undifferentiated input—often proxied by R&D expenditure, patent counts, or composite technology indices—and assumes a direct link between innovation, productivity, and growth. While analytically convenient, this approach collapses in distinct stages of the innovation process, from investment and knowledge creation to diffusion, absorption, and

Frontier technologies can be transformative for Africa only when embedded in broader development strategies that address institutional quality, infrastructure gaps, human capital constraints, and distributional concerns.

structural reallocation. As a result, it obscures the points at which the innovation–growth relationship may weaken or break down and provides limited insight into delayed or uneven productivity responses.

These limitations are particularly acute in Africa. Many African countries invest in frontier technologies and digital infrastructure without realizing commensurate productivity gains. This is not because innovation is ineffective, but because key complementarities—skills, institutions, finance, infrastructure, and diffusion mechanisms—are insufficiently developed. Conventional models struggle to capture these constraints and the cumulative, path-dependent nature of innovation-led development. The framework here addresses these gaps by unpacking innovation into sequential stages with explicit feedback loops, clarifying how and under what conditions frontier technologies translate into productivity gains, structural transformation, and sustainable growth in Africa (figure 2.8). Rather than treating innovation as a single input, it is structured as a five-stage causal sequence with reinforcing feedback mechanisms, capturing both the sequencing and cumulative nature of effects.

Figure 2.8 Conceptual framework for innovation-led growth



Note: Solid arrows denote forward casual effects; dashed arrows denote feedback loops. Time lags vary with institutional quality, skills, finance and diffusion capacity.

Source: Conceptualised by the authors, 2025.

1. Foundational enablers (system preconditions)

The first cluster represents the deep structural conditions that determine whether innovation can emerge and be absorbed. It consists of human capital development; institutional and governance quality; infrastructure readiness; financial system depth; entrepreneurial ecosystem development. These elements do not directly raise productivity, but they condition the returns to all subsequent innovation activity. Weak foundations imply that innovation inputs will yield only shallow or short-lived effects. Strong foundations, by contrast, lower transaction costs, reduce risk, improve coordination, and enhance absorptive capacity across firms and sectors.

This cluster corresponds directly to the "enabling environment" highlighted in endogenous growth and institutional growth theories (Romer–Lucas–North–Acemoglu et al.).

2. Innovation inputs (intentional resource commitments)

Cluster 2 captures purposeful investments and policy-driven efforts to generate or access new knowledge and technologies. These flow variables represent active effort, not productive capability: R&D investment and expenditure; knowledge outputs-publications, patents; digital and ICT investment; collaborative research and innovation platforms; initial innovation networks and partnerships.

These inputs represent attempted innovation, but do not yet guarantee productivity outcomes. At this stage, knowledge is still fragmented, experimental, and weakly diffused. Importantly, this cluster measures effort, not economic usability.

3. Knowledge and technology accumulation (absorptive and diffusion capacity)

Cluster 3 captures the stock and economywide embedding of knowledge, not the flow of innovation effort. It represents the transformation of inputs into usable productive capability through skills formation

and learning-by-doing; institutional learning and absorptive capacity; technology diffusion and widespread ICT penetration; and cross-sector spillovers and imitation effects. This is the critical conversion stage where innovation inputs become economically meaningful (it aligns directly with the LP–SGMM empirical results below, where: FTRI impacts on TFP become positive only after years 2–3. The delay reflects the time needed for knowledge accumulation and diffusion.

4. Productivity gains (economic efficiency outcomes)

Once knowledge is embedded and diffused, it produces measurable efficiency and quality improvements, captured in cluster 4: total factor productivity (TFP) growth; technical and allocative efficiency improvements; quality upgrading and standards compliance and process and product innovation.

5. Structural transformation and sustainable growth (final outcomes)

In the final stage, persistent productivity gains drive long-term structural change: economic diversification; value addition and global/regional value-chain upgrading; job creation and improved employment quality and sustainable growth trajectories. This cluster captures the macroeconomic reallocation effects of innovation: labour shifts from low-productivity to high-productivity sectors; firms upgrade technologically; production structures become more complex and resilient.

The framework explicitly embeds three reinforcing feedback mechanisms:

- **Knowledge accumulation** → Productivity → New innovation investment; productivity gains generate profits, fiscal space, and learning effects that stimulate further R&D and technology investment.
- **Productivity** → Structural transformation → Stronger foundations; structural transformation strengthens institutions, infrastructure, finance, and skills systems, reinforcing cluster 1.
- **Growth** → System upgrading →Higher innovation returns; as economies become more diversified and complex, the returns to innovation rise, deepening the next cycle.

These dynamics explain why innovation-led growth is nonlinear, cumulative, and path-dependent, and why delayed productivity effects are a structural feature rather than an empirical anomaly.

HARNESSING INNOVATION AND TECHNOLOGY FOR PRODUCTIVITY-DRIVEN GROWTH IN AFRICA

Building on the theoretical and empirical review, this section examines how frontier technologies are associated with productivity and economic growth in Africa.[39] The analysis centres on total factor productivity (TFP) as the key transmission channel for technology and innovation to affect growth, allowing a clear distinction between enabling conditions, productivity outcomes, and aggregate economic performance. To capture these enabling conditions, the study employs UNCTAD's Frontier Technology Readiness Index (FTRI), a multidimensional measure encompassing skills, ICT infrastructure, access to finance, and related capabilities.

Jointly analysing productivity and growth outcomes using a broad measure of technological readiness provides more nuanced evidence on where and how frontier technologies are linked to economic performance. Recent improvements in data availability—most notably the FTRI—enable systematic cross-country analysis over time and allow the results to inform policy more directly, particularly by identifying which dimensions of readiness are most closely associated with productivity and growth.

Accordingly, the analysis provides evidence on the relationship between frontier technologies and productivity outcomes, their association with economic growth, and the relative importance of different readiness dimensions—such as skills, ICT infrastructure, finance, and industrial capacity—in shaping these outcomes. By disaggregating these relationships, the results help identify where policy constraints are most binding and where targeted interventions are likely to yield the greatest productivity and growth dividends, while underscoring the need for careful interpretation of composite indicators.

The FTRI, though well suited to this purpose, requires caution. As a composite index, it aggregates components measured with varying precision, involves normative weighting choices, and combines indicators of readiness with elements reflecting actual use. It is thus interpreted here as an indicator of the enabling environment for frontier technologies rather than a direct measure of technological capability. The empirical results should be read as identifying associations between technological readiness and productivity and growth outcomes, underscoring that frontier technologies are most likely to support Africa's long-term growth when embedded in coherent innovation ecosystems that align infrastructure, skills, finance, and institutions.

FRONTIER TECHNOLOGIES AND PRODUCTIVITY OUTCOMES

Technology and innovation activities exert a delayed but long-term positive impact on productivity in Africa. The results of the empirical study on the impact of technology and innovation on TFP indicate that technology and innovation (captured by FTRI) exert no immediate effect on productivity in year 0 but turns positive and statistically significant from year 1 onwards.[40] The effect strengthens through year 2 and peaks in years 3 and 4 at roughly 0.34 percentage points increase in TFP for a one-unit increase in FTRI, before tapering off modestly by year 5 reaching 0.26 percentage points (figure 2.9).[41] Economically, this implies that a one-unit increase in FTRI is associated with sustained productivity gains of more than a quarter of a percentage point even five years after the initial improvement. These magnitudes are

The results of the empirical study on the impact of technology and innovation on TFP indicate that technology and innovation (captured by FTRI) exert no immediate effect on productivity in year 0 but turns positive and statistically significant from year 1 onwards.

not trivial when set against the typically modest average TFP growth rates in the sample, indicating that improvements in technology and innovation accelerate productivity dynamics substantively. In addition, the results confirm the strong persistence of TFP as the first lag is consistently large and highly significant, implying that past productivity levels have strong impact on current performance, whereas the second lag remains insignificant, which is consistent with a dynamic process in the short run.

So, for Africa as a whole, using an estimated 2025 GDP of $3.1 trillion,[42] the year 5 effect of a one-unit increase in FTRI translates into about $8.1 billion in additional output, corresponding to 0.26 percentage points of TFP growth applied to the continent's GDP in 2025 (see annex tables A2 and A3).

The dynamic pattern of effects is consistent with the strong persistence of productivity observed in the estimates. The first lag of TFP is large and highly significant, indicating that past productivity levels strongly influence current performance, while the second lag is insignificant, reflecting short-run adjustment dynamics rather than long-term inertia. Together, these results point to a gradual transmission process rather than an immediate productivity response.

Importantly, the delayed effects should not be interpreted as statistical artefacts but as reflecting underlying economic mechanisms highlighted in the conceptual framework (cluster 3 in figure 2.8). Several complementary processes help explain why frontier technology and innovation translate into productivity gains only over time.

First, learning-by-doing effects play a central role. The adoption of new technologies typically requires experimentation, adaptation, and incremental improvements at the firm and sectoral levels. Productivity gains materialize only after workers and firms accumulate experience in using new technologies efficiently, reorganizing production processes, and adjusting business models.

Second, absorptive capacity building is critical. Frontier technologies often require complementary investments in skills, managerial capabilities, and organizational practices. Improvements in technology readiness may initially expand access to new tools,

For Africa as a whole, using an estimated 2025 GDP of $3.1 trillion, the year 5 effect of a one-unit increase in FTRI translates into about $8.1 billion in additional output, corresponding to 0.26 percentage points of TFP growth applied to the continent's GDP in 2025.

but productivity gains emerge only when firms and workers develop the capacity to absorb, adapt, and integrate these technologies into production. This is particularly relevant in African economies, where skill gaps and limited R&D capacity can delay the realization of productivity benefits.

Third, institutional mediation shapes the speed and strength of transmission. Regulatory frameworks, standards, procurement systems, and public-sector coordination influence how rapidly new technologies diffuse and scale across the economy. Weak institutions can slow this process, while gradual institutional learning and policy adaptation can help unlock productivity gains over time. The lagged effects are thus consistent with institutional adjustment processes rather than immediate responses.

Overall, these mechanisms align closely with the conceptual framework, which emphasizes that technology and innovation influence productivity through a sequence of complementary adjustments rather than instant efficiency gains. The results underscore that frontier technologies become productivity-enhancing only when learning, absorptive capacity, and institutional support evolve in tandem.

These dynamics have important policy implications. The presence of multiyear lags implies that investments in technology and innovation require sustained commitment and realistic expectations. Policymakers should not expect immediate productivity payoffs from improvements in technology readiness but rather anticipate gradual gains that build over several years. Maintaining consistent

investment in skills development, institutional strengthening, and complementary infrastructure over this horizon is therefore essential to fully realize the productivity benefits of frontier technologies.

The absence of significant productivity effects from foreign direct investment (FDI) inflows and trade openness is consistent with longstanding findings in the African development literature. One explanation lies in the enclave nature of FDI, which in many African economies is concentrated in extractive sectors with limited backward and forward linkages to domestic firms, resulting in weak technology spillovers and limited learning effects.[43] A second explanation relates to resource-biased trade patterns. Trade openness in Africa has largely reflected exports of primary commodities and imports of consumption and capital goods, constraining learning-by-exporting and technology diffusion that have supported productivity growth elsewhere.[44] In such contexts, greater integration into global markets does not automatically translate into productivity gains when export structures remain weakly diversified.

Crucially, the productivity effects of both FDI and trade are conditional on domestic absorptive capacity and technological readiness. Where skills, technological capabilities, and institutional support are limited, foreign investment and trade exposure tend to reinforce existing production structures rather than drive upgrading. This conditionality underscores that capital inflows and openness are not productivity-enhancing in isolation but depend on complementary investments in skills, technology adoption, industrial capacity, and institutions—dimensions closely aligned with frontier technology readiness.[45]

Human development capacity captured by the Human Development Index (HDI) is found to exert a negative impact on productivity, to some extent suggesting that the available human capital is not conducive to technology and innovation enhancement in most countries. This result should, however, be interpreted with caution and does not imply that human capital is detrimental to productivity growth. Instead, it reflects limitations in how broad human development indicators map onto the skills and capabilities required for technology adoption and productivity enhancement.

Policymakers should not expect immediate productivity payoffs from improvements in technology readiness but rather anticipate gradual gains that build over several years.

First, aggregate HDI measures do not capture the specific technical, digital, and managerial skills to absorb frontier technologies. Improvements in schooling or health outcomes may therefore yield limited productivity returns where education quality is low or skills are poorly aligned with technological needs, consistent with earlier evidence.[46] Second, conditional on frontier technology readiness, the additional explanatory power of broad human development indicators becomes ambiguous, as key skill-related channels are already captured elsewhere in the model. Third, short-run demographic effects associated with health improvements may temporarily dampen measured productivity in economies facing rapid population growth and limited structural transformation.[47]

Finally, institutional quality conditions the productivity impact of human capital. Where institutions are weak, gains in education and health may not translate into productive employment or technology-intensive activity, reinforcing the complementarity between human development and governance capacity.

Overall, the result does not contradict human capital theory but highlights that human development contributes to productivity primarily when aligned with technology adoption and strong institutions. From a policy perspective, this underscores prioritizing targeted skills development and education–technology complementarities—such as technical and vocational training, digital skills, and managerial capabilities—rather than relying on aggregate human development indicators alone to drive productivity growth.

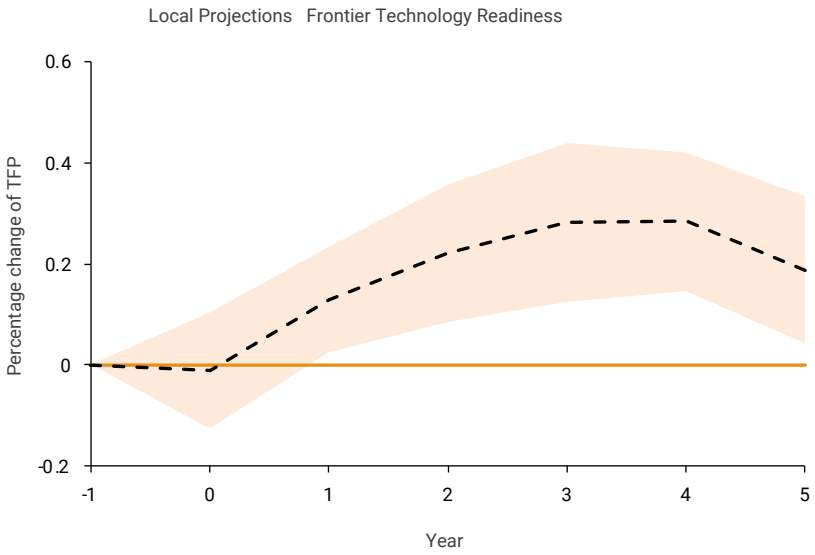
Institutional quality is also found to be a long-term enabling factor that consolidates and sustains productivity benefits of technology and innovation. These results suggest that while traditional growth drivers such as FDI and trade remain weak in enhancing productivity, human development and institutional frameworks interact with technology and innovation activities to become critical drivers for sustaining productivity gains.

ICT deployment, skill, and industrial activities

Disaggregating the Frontier Technology Readiness Index (FTRI) into its constituent dimensions reveals that the productivity effects of technology and innovation in Africa operate through distinct mechanisms, with markedly different time profiles and policy implications (figure 2.10). Rather than contributing uniformly, the various components affect productivity through three broad channels: human capital accumulation, industrial absorption and use, and enabling infrastructure and finance.

At the core of the framework is the productivity absorption mechanism, driven by skills and human capital. Skill capabilities display a strongly negative short-run effect on total factor productivity, followed by a decisive and statistically significant positive effect in the medium term (years four and five). This pattern reflects adjustment and training costs, learning-by-doing, and transitional labour-market frictions that temporarily weigh on productivity before efficiency gains materialize. Skills operate as a foundational input that determines whether frontier technologies can be absorbed, adapted, and effectively deployed (see figure 2.8). Without adequate human capital, technological readiness does not translate into productivity gains.

Figure 2.9 Impulse response functions for change in technology and innovation



Source: ECA calculations.
Note: The chart shows the impulse response of TFP to changes in the Frontier Technology Readiness (FTR) Index, estimated using Local Projections combined with System GMM. The estimation uses lags of the endogenous variables (≥ 2) as instruments to address potential endogeneity. Year 0 represents the contemporaneous effect, while the line at year 5 captures the cumulative impact of the FTR Index on TFP five years later. The dashed-line plots the estimated coefficients, and the shaded area represents the 90% confidence interval.

Industrial activity represents the primary channel through which technology is embedded into production. Industry-related activity—particularly in high-tech manufacturing, ICT-related sectors, and digital services—emerges as the most consistent and immediate contributor to productivity, with positive and statistically significant effects throughout the five-year horizon. This finding aligns with the framework's emphasis on productive use and structural transformation: frontier technologies raise productivity most effectively when they are deployed within active industrial and service ecosystems that enable scale, learning, and spillovers. Industrial activity thus functions as the main conduit for transforming technological readiness into sustained productivity growth.

ICT deployment plays a supporting but conditional role in the framework. ICT infrastructure contributes positively to productivity only in the medium term, with significance emerging around year three. This delayed and limited effect reflects the quality, reliability, and coverage constraints of digital infrastructure across the continent. Within the theoretical framework, ICT functions as an enabling input rather than a standalone driver: it amplifies the productivity effects of skills and industrial activity but does not generate sustained gains in their absence. This reinforces the view that digital infrastructure

investments must be closely aligned with productive use and human capital development.

By contrast, R&D activity and access to finance do not yet operate as effective productivity channels. Frontier technology–related R&D, proxied by publications and patents, shows insignificant or negative effects on productivity, reflecting weak innovation systems, limited research–industry linkages, and the long gestation periods required for research outputs to translate into economic value. Similarly, access to finance—measured by domestic credit to the private sector—does not exhibit a systematic productivity-enhancing effect, suggesting inefficiencies in financial allocation and a bias toward consumption or low-productivity activities. In the framework, these pillars represent latent enablers whose potential remains underutilized due to institutional and structural weaknesses.

The overall results point to strong complementarities rather than substitutability across FTRI pillars. Skills, industrial activity, and ICT deployment reinforce one another along the productivity transmission chain, while weaknesses in R&D systems and financial intermediation constrain the depth and sustainability of productivity gains. This explains why technology adoption in Africa has often produced shallow or short-lived effects despite visible progress in digital diffusion.

Implications for FTRI pillar reform sequencing

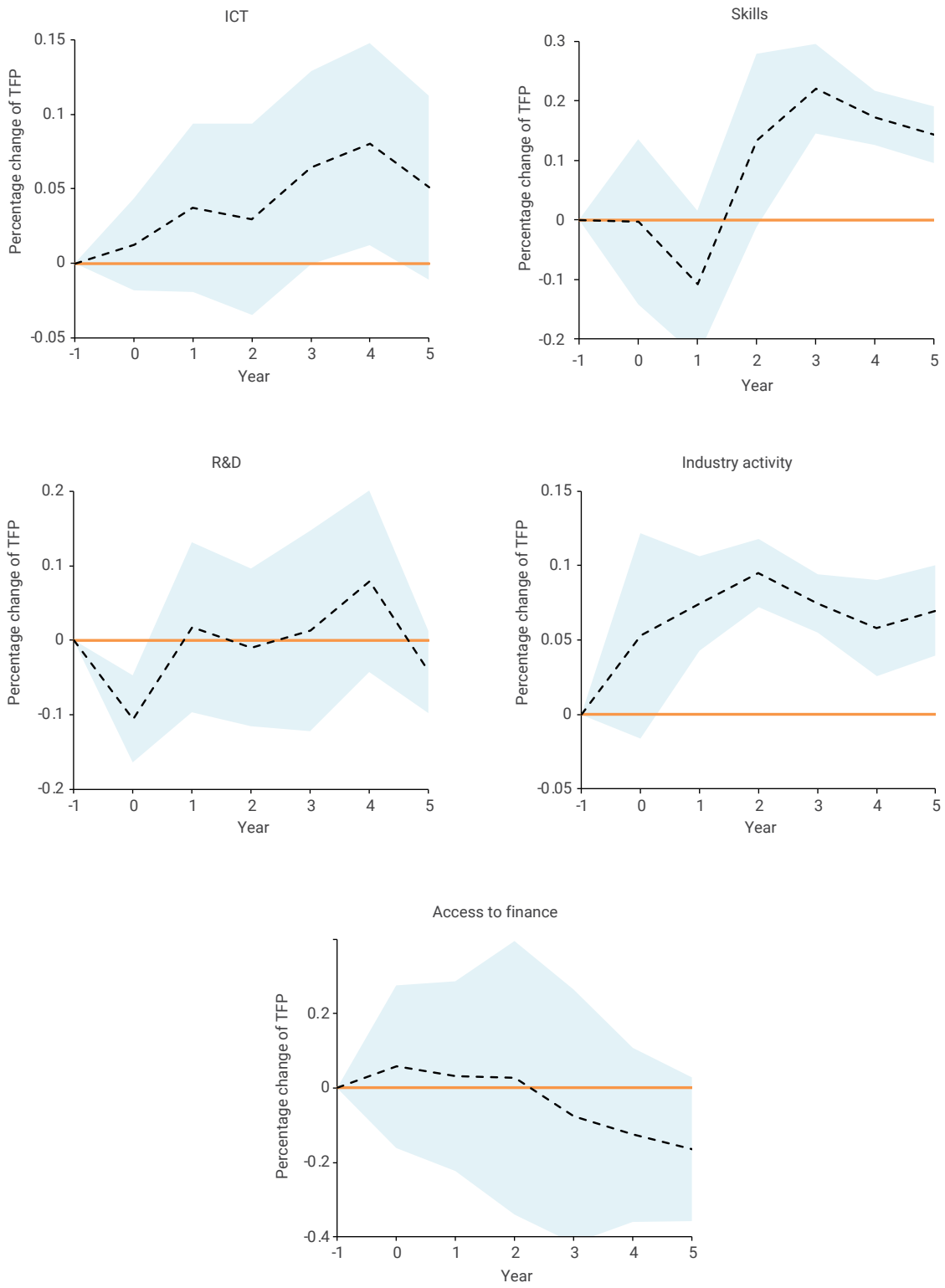
Anchored in the theoretical framework and supported by the empirical results, a clear sequencing of reforms emerges. First, priority should be given to skill development and industrial capability, as these form the core absorption and productive-use mechanisms through which frontier technologies affect productivity. Second, ICT infrastructure investments should be scaled up in tandem, with an explicit focus on quality, reliability, and integration into productive sectors, rather than on access alone.

Skills, industrial activity, and ICT deployment reinforce one another along the productivity transmission chain, while weaknesses in R&D systems and financial intermediation constrain the depth and sustainability of productivity gains. This explains why technology adoption in Africa has often produced shallow or short-lived effects despite visible progress in digital diffusion.

Third, R&D systems and financial intermediation require targeted reforms to strengthen linkages with industry, improve allocation efficiency, and support technology adoption and upgrading. Addressing these pillars in isolation is unlikely to deliver sustained productivity gains; coordinated and sequenced reforms are essential.

In line with figure 2.8, the findings underscore that frontier technologies become growth-enhancing in Africa not through their mere availability, but through their integration into a coherent ecosystem that aligns human capital, industrial activity, digital infrastructure, and enabling institutions. Only under such conditions can technological readiness be transformed into durable productivity growth and structural transformation.

Figure 2.10 Impulse response functions for change in the FTRI components on TFP



Source: ECA calculations.

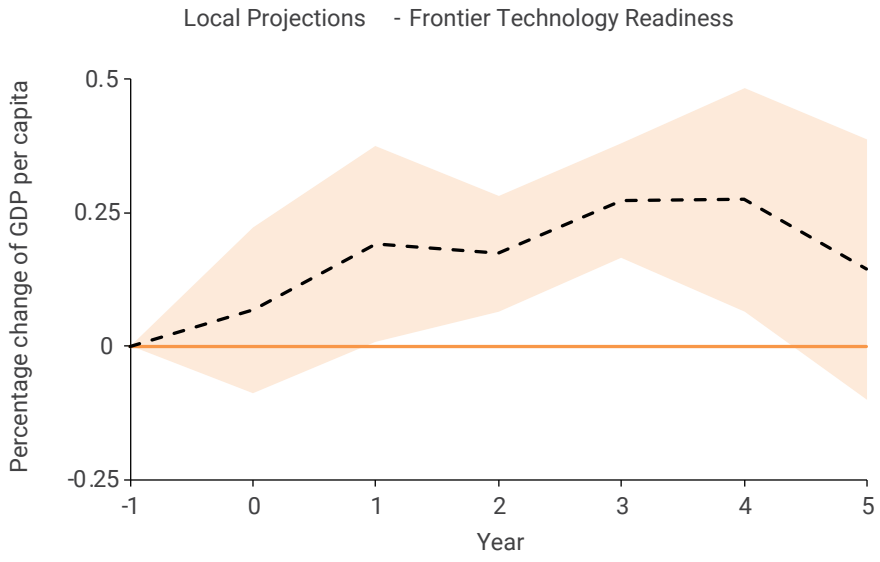
Frontier technologies and innovation are not only productivity drivers, but growth enablers as well. While total factor productivity (TFP) provides a critical lens for understanding the efficiency gains associated with technology and innovation, it is ultimately economic growth and income dynamics that determine whether these gains translate into higher living standards. For this reason, the analysis here extends the specification to incorporate GDP per capita to capture the broader developmental payoffs of frontier technologies and innovation.

The Frontier Technology Readiness Index (FTRI) shows a gradual but significant effect on growth, as it is marginally significant in the short term (at 0.38 percentage points), and strengthen considerably in the medium term, before tapering off at slightly lower levels (of 1.049–0.975 percentage points) (figure 2.11). This trajectory indicates that the adoption and utilization of frontier technologies and innovation require time to diffuse and embed into the economy, but once established, they exert a sizable impact on income growth. The results show that by the fifth year, the growth effects of frontier technologies and innovation could translate into substantial monetary gains across Africa, as one-unit increase could lead to an improvement of nearly $2,000 in GDP per capita, while boosting total GDP by about $27.5 billion, equivalent to almost one year's worth of income at baseline levels.

Trade openness and institutional quality are also found to exert a positive role in per capita growth. The results highlight how integration into global markets amplifies the growth effects of innovation. While institutional quality results are consistent with the notion that stable and effective institutions create an enabling environment for growth, even if they do not act as a direct driver of growth in the short-term.

Overall, frontier technologies and innovation are not only drivers of productivity but also powerful enablers of per capita income growth. Crucially, their benefits take time to materialize, reflecting the slow process of adoption, diffusion, and integration into production systems. This highlights the importance of policies that sustain innovation-friendly environments over time, particularly through investment in skills development, industrial upgrading, and trade integration, so that the gains from technological progress translate into significant improvements in living standards (see figure 2.11).

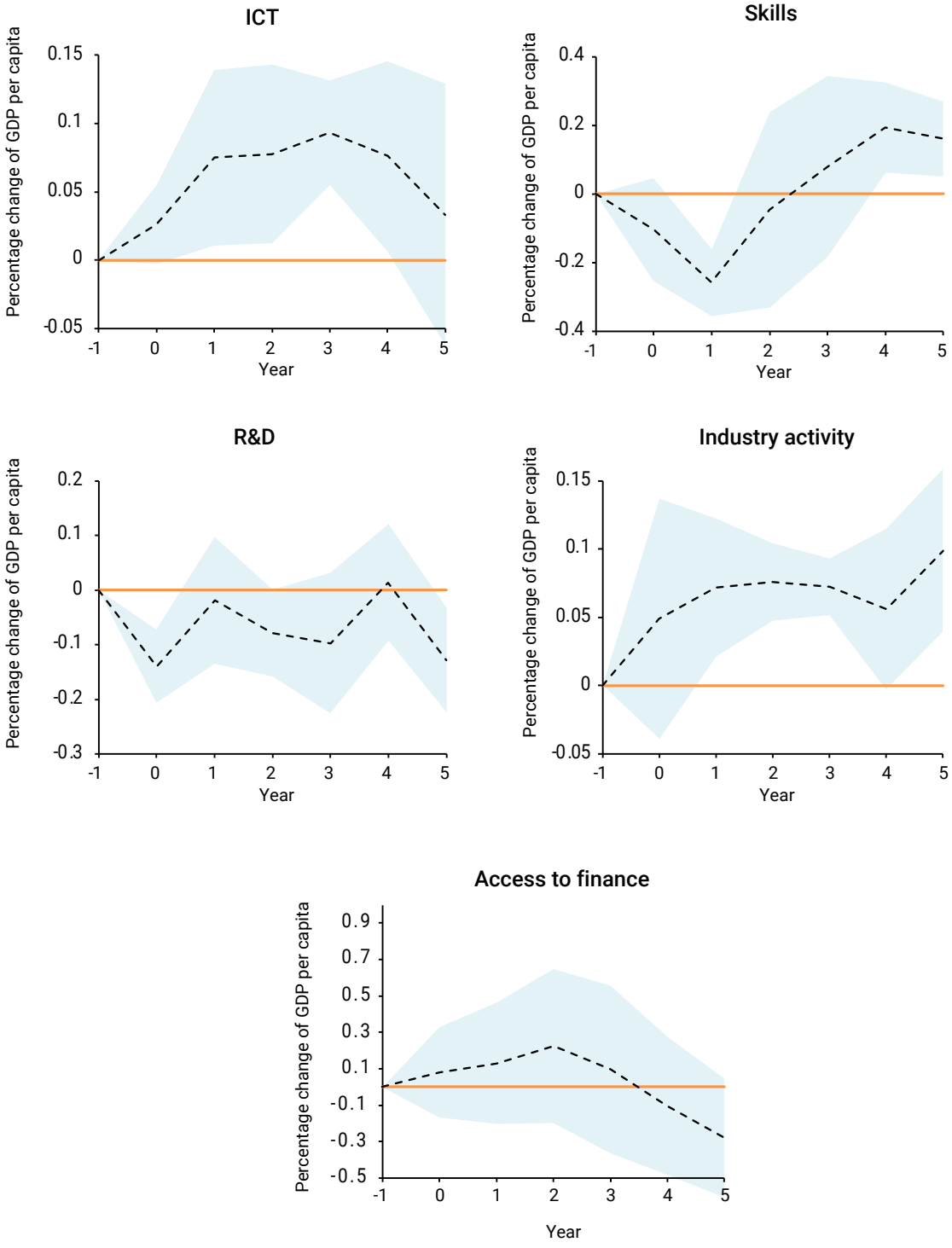
Figure 2.11 Impulse response function for change in the FTRI on per capita growth



Source: ECA calculations.
Note: The figure shows the impulse response of GDP per capita to changes in the Frontier Technology Readiness (FTR) Index, estimated using Local Projections combined with System GMM. The estimation uses lags of the endogenous variables (≥ 2) as instruments to address potential endogeneity. Year 0 represents the contemporaneous effect, while the line at year 5 captures the cumulative impact of the FTR Index on GDP per capita five years later. The solid line plots the estimated coefficients, and the shaded area represents the 90 per cent confidence interval.

Viewed through the theoretical framework, the disaggregated growth results confirm that frontier technologies influence GDP per capita in Africa through sequenced and complementary mechanisms, rather than through uniform or immediate effects (see figure 2.8). Indeed, the growth impact of technology and innovation depends critically on the interaction between human capital, productive use, and enabling infrastructure, with distinct short- and medium-term dynamics (figure 2.12).

Figure 2.12 Impulse response functions for change in the FTRI components on per capita growth



Source: ECA calculations.

Skill development operates as a medium-term growth mechanism. The skills component exhibits a U-shaped response: negative effects in the short run (years 1–2), reflecting training and adjustment costs, followed by positive and sustained gains from years 3 to 5, amounting to roughly 0.2–0.3 percentage points in GDP per capita growth. This pattern is consistent with the framework's emphasis on absorptive capacity: investments in human capital initially impose costs but are essential for translating frontier technologies into durable growth gains over time.

Industry activities provide the most stable and immediate growth channel. Industry-related activities—particularly high-tech manufacturing, ICT, and digital services—show consistently positive contributions to GDP per capita from year 1 onward, peaking around years 3–4. This confirms the role of productive sectors as the main conduit to embed technology and innovation in economic activity, reinforcing the finding that growth dividends from frontier technologies are strongest when linked to structural transformation and industrial upgrading.

ICT deployment plays a short-run, complementary role. It generates modest but statistically significant growth effects in the early years, before flattening out. This pattern suggests that digital diffusion alone can deliver quick gains but does not sustain growth unless combined with skills development and industrial capacity. Within the framework, ICT functions as an enabling input that amplifies other mechanisms rather than as an independent driver of long-term growth.

R&D and access to finance remain weak or misaligned growth channels. R&D and access to finance emerge as weak or misaligned channels for productivity-led growth. The R&D component exhibits volatile and statistically insignificant effects, reflecting persistently low R&D intensity, weak linkages between research systems and productive sectors, and the long gestation periods required before innovation investments translate into measurable productivity gains. In contexts where absorptive capacity is limited, and firm-level innovation ecosystems remain underdeveloped, R&D spending does not yet generate systematic growth effects.

Access to finance displays a short-lived positive association with productivity, followed by negative effects after the third year, indicating that financial resources are not consistently channelled toward technology- and innovation-enhancing activities. Rather than reflecting an absence of financial depth, this pattern points to institutional and allocation failures in financial intermediation. Financial expansion in many African economies remains concentrated in nontradable and low-learning sectors. It operates on short time horizons ill-suited to innovation, and is frequently crowded out by public financing needs. In addition, limited firm capabilities and weak innovation systems constrain the productive use of credit, while commonly used indicators of financial access primarily capture transactional and inclusion-oriented finance, rather than long-term, risk-bearing investment finance.

Overall, these dynamics imply that financial deepening in the current forms does not automatically translate into productivity gains. Without improvements in allocation mechanisms, absorptive capacity, and institutional linkages to productive sectors, just increasing access to finance risks reinforcing low-productivity growth patterns, underscoring the need to reorient policy from expanding volumes towards improving quality, targeting, and sequencing.

Replacing the FTRI with the Global Innovation Index (GII) yields weaker and, in the medium term, negative growth effects, underscoring the limitations of conventional innovation measures that focus primarily on inputs. By contrast, the FTRI—by capturing readiness conditions alongside innovation effort—shows a positive and significant relationship with GDP per capita. This contrast reinforces the central insight of the framework: innovation yields growth dividends only when enabling conditions are in place.

Consistent with the framework here, the results suggest a clear ordering of priorities. First, skill development and industrial capability should be strengthened, as they constitute the core mechanisms through which frontier technologies translate into sustained growth. Second, ICT infrastructure should be expanded and upgraded in ways that directly support productive and industrial use. Third, financial intermediation requires targeted reforms to strengthen its linkages with the productive sector and to ensure that financial

resources support technology adoption, upgrading, and firm-level learning, rather than short-term or low-productivity uses. Addressing these pillars in isolation is unlikely to generate durable growth gains; instead, coordinated and properly sequenced reforms are essential.

The policy challenge is therefore not to expand finance indiscriminately, but to improve its quality, allocation, and sequencing. Financial deepening must be accompanied by mechanisms that channel resources toward productive and technology-intensive activities, extend investment horizons, strengthen firm-level absorptive capacity, and limit crowding out arising from public financing needs. Without these complementary reforms, additional finance risks reinforcing low-productivity growth patterns, rather than supporting sustained productivity growth and structural transformation.

SECTORAL PRODUCTIVITY GROWTH

Technology and innovation play a key role in driving productivity growth in manufacturing and services sectors but remain elusive in driving the agriculture sector.[48] The extension of the analysis to these three main sectors provides critical insights into how technology and innovation affect productivity in different parts of the economy. Since the impact of frontier technologies and innovation may vary substantially across sectors depending on their structural characteristics, vulnerability to shocks, and capacity for innovation, understanding these heterogeneous effects is key for designing targeted policies that could accelerate structural transformation, boost productivity, and foster inclusive growth.

Agriculture shows no consistent productivity gains from frontier technology readiness, with elasticity turning negative at −0.17 percentage point in year 2 (figure 2.13). This outcome reflects the sector's well-known structural vulnerabilities. Agriculture in much of Africa remains highly dependent on rainfall and low-productivity smallholder systems, with limited irrigation, mechanization, or digital penetration. In such settings, higher national technology readiness may not filter down to farmers or may even impose adjustment costs in the short run if new practices disrupt traditional production methods.

Financial deepening must be accompanied by mechanisms that channel resources toward productive and technology-intensive activities, extend investment horizons, strengthen firm-level absorptive capacity, and limit crowding out arising from public financing needs.

Manufacturing displays a strong and persistent positive response to frontier technologies and innovation, with elasticities increasing from 0.19 percentage point at year 1 to a peak of 0.34 percentage point at year 4 (figure 2.13). This suggests that frontier technologies are gradually being integrated into industrial processes, generating scale economies, efficiency gains, and spillovers into related industries. Africa's emerging industrial hubs, particularly in light manufacturing, agroprocessing, and automotive assembly, are better positioned to absorb digital and automation technologies, which could partly be underpinning the gradual positive impact. Manufacturing emerges as the sector most consistently boosted by frontier technologies and innovation, and with the greatest potential to anchor structural transformation.

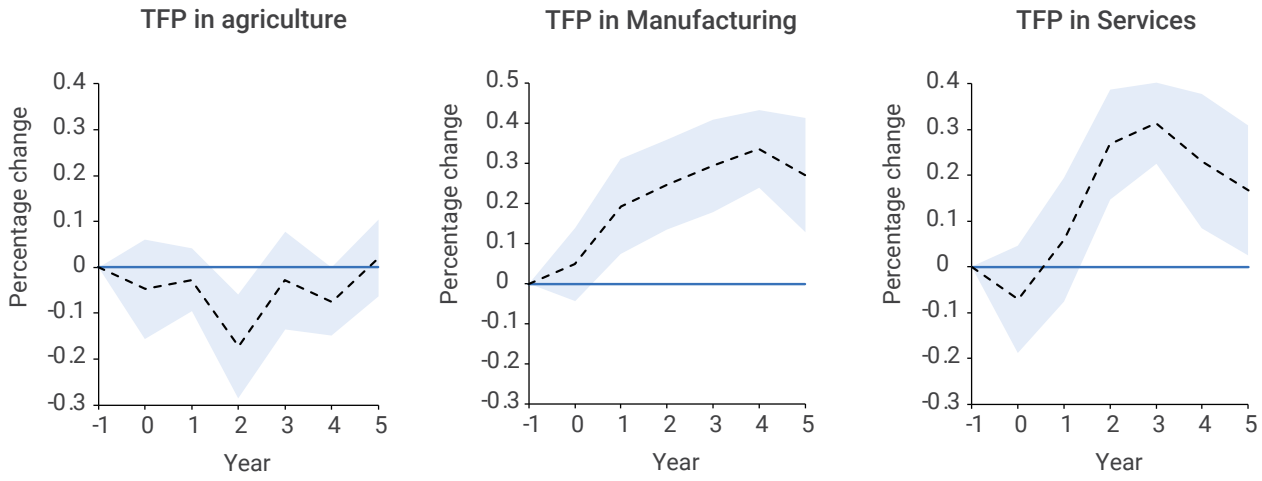
Services strongly benefit from frontier technologies and innovation, with elasticity peaking at 0.27 in year 2 and remaining robust at 0.23 percentage points in year 4. The results mirror the rapid uptake of digital technologies across service sectors in Africa, from fintech to logistics and e-commerce, which directly enhance productivity by lowering transaction costs and expanding access to markets.

Trade openness has a positive impact on productivity in all three sectors, indicating the significance of integration into global markets in enhancing productivity in African economies. Institutional quality has a positive impact only in agriculture and manufacturing suggesting that stronger governance improves the sector's ability to absorb new agricultural practices and long-term industrial

upgrading, respectively. However, institutional quality is found to have an insignificant impact on productivity in the services sector, suggesting that services depend more directly on technology uptake than on governance structures.

Overall, the results imply that frontier technologies and innovation are already driving productivity growth in manufacturing and services, but their benefits remain elusive in agriculture, where structural bottlenecks and vulnerabilities to external shocks still dominate.

Figure 2.13 Impulse response functions for change in the FTRI on sectoral TFP

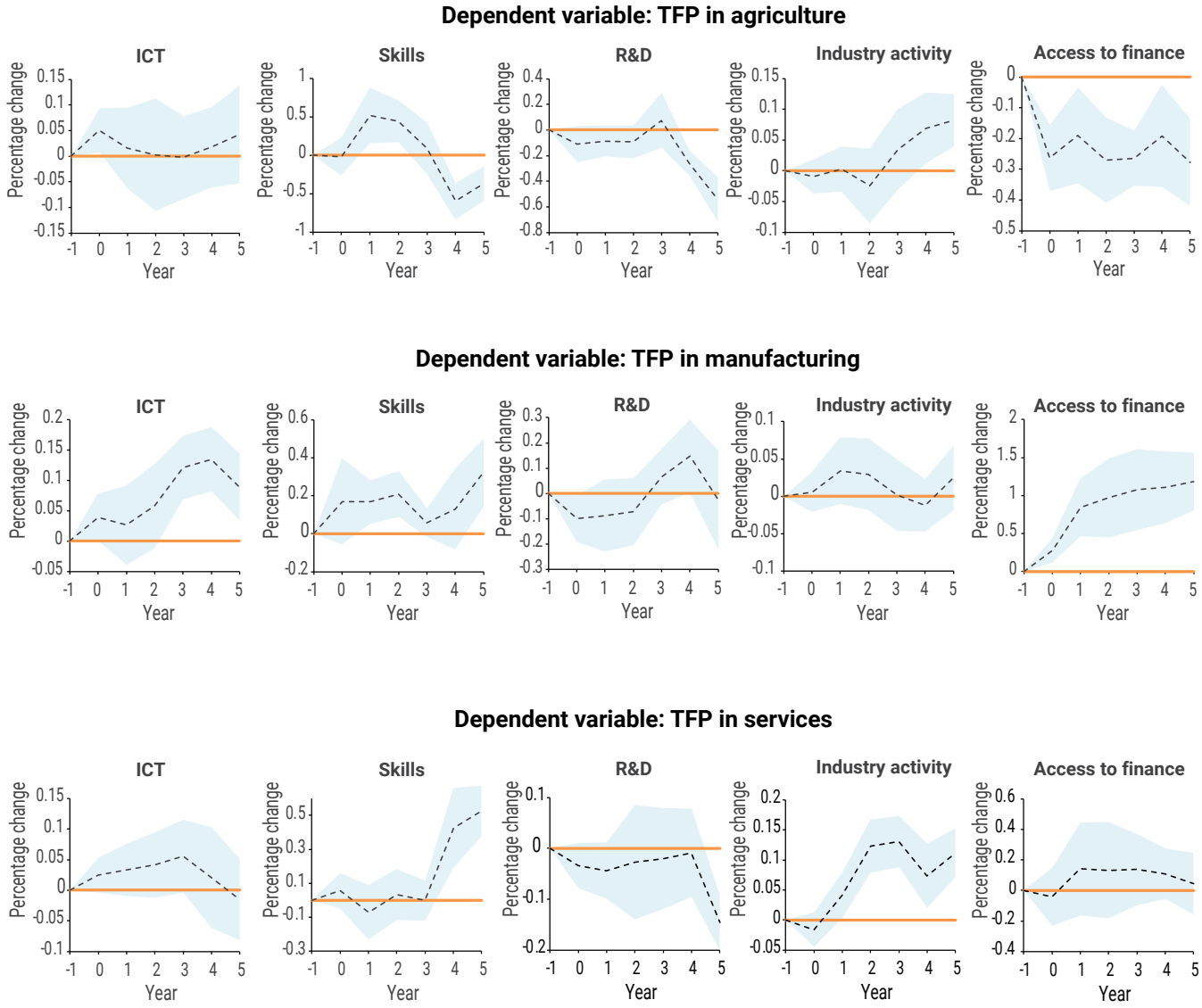


Source: ECA calculations.

ICT deployment, skills development, R&D, enhanced industrial ecosystems, and access to finance remain critical to sectoral productivity growth through technology and innovation. This section considers the impact of technology and innovation components of skill development, ICT deployment, R&D, industry activity, and access to finance, the components of the FTRI (figure 2.14). In agriculture, ICT deployment is found to have minimal positive impact, suggesting that digital adoption alone does not significantly raise productivity in African economies, especially in rural economies where ICT penetration remains relatively low. Skills show a short-lived boost around year 2, but the effect fades thereafter, indicating the need for continuous education and training which could help farmers adopt new and better practices. R&D is found to have a persistently negative effect, especially after year 3, to some extent reflecting the weakness of agricultural research systems in Africa and the limited delivery of sector-specific technologies.

Agriculture shows no consistent productivity gains from frontier technology readiness, with elasticity turning negative at –0.17 percentage point in year 2.

Figure 2.14 Impulse response functions for change in the FTRI components on sectoral TFP



Source: ECA calculations.

In agriculture, ICT deployment is found to have minimal positive impact, suggesting that digital adoption alone does not significantly raise productivity in African economies, especially in rural economies where ICT penetration remains relatively low.

Industry activity contributes modest positive effects, showing that agroprocessing and linkages with broader industrial activity can indirectly raise farm productivity. Access to finance, however, has a strong and lasting negative effect, highlighting the severe credit constraints being faced by farmers and also even when finance may be available, it may not be channelled into productivity-enhancing areas. These results suggest that agriculture is the least able to translate technology readiness into productivity gains, with finance and R&D emerging as the most critical bottlenecks to be addressed.

In manufacturing, ICT deployment has a strong and steadily increasing effect, reflecting the role of digital technologies in enhancing efficiency across

production processes and logistics in the sector. Skills show a gradual and persistent positive impact, underscoring the importance of vocational training and technical expertise in supporting industrial upgrading. R&D shows a weak impact initially, before having a positive and significant impact after year 3, suggesting that investments in industrial research take time before contributing to productivity improvements in the sector. Industry activity has a clear and positive effect throughout, demonstrating that dense industrial ecosystems generate spillovers that raise sectorwide efficiency. Access to finance stands out as the single most powerful driver, with a strong and persistent positive impact, highlighting that manufacturing—being capital-intensive—relies heavily on credit and investment to sustain productivity growth. It is the sector most responsive to frontier technology readiness, with finance, ICT, and skills the main engines of sustained productivity gains.

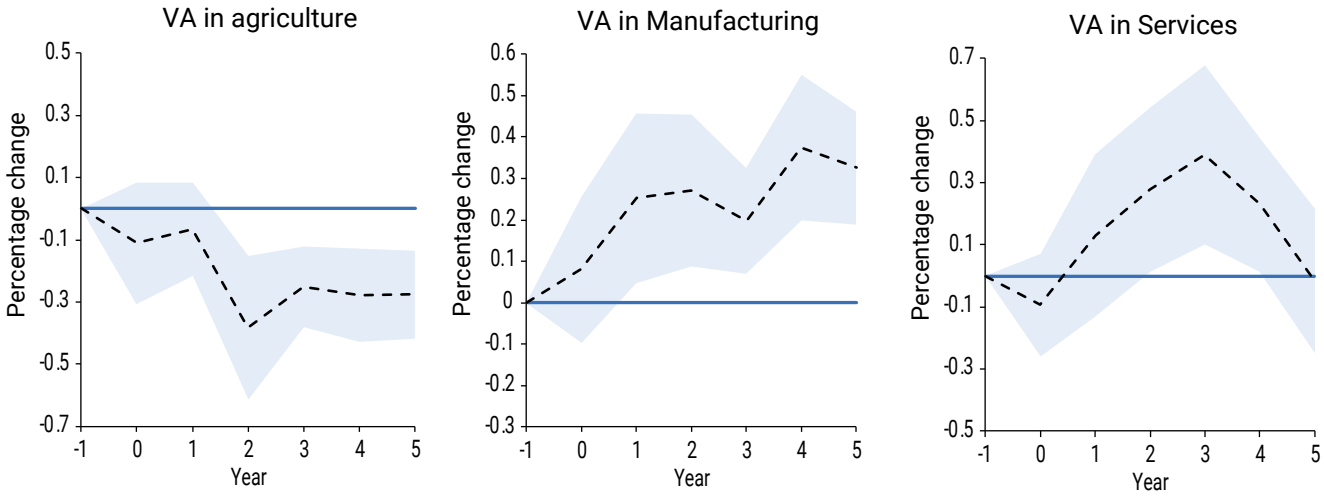
In services, ICT deployment shows a steady and positive effect, reflecting the central role of digitalization in activities such as telecommunications, finance, and logistics. Skills are initially flat but rise strongly after year 3, suggesting that as human capital improves, services productivity can catch up with the pace of digital transformation. R&D remains slightly negative and largely insignificant, so services innovation in Africa is less about formal R&D and more about diffusion, adaptation, and new business practices. Industry activity generates positive medium-term effects, showing that services benefit from linkages to trade and industrial expansion. Access to finance has a strong and persistent positive effect, underscoring that service-sector growth—particularly in SMEs, ICT, and finance—depends critically on credit availability. In sum: services benefit most from ICT and finance, with skills becoming increasingly important over time, while formal R&D remains of limited relevance for their productivity.

Disaggregating by value added

While sectoral TFP analysis sheds light on productivity dynamics, disaggregating by value added (VA) provides an additional and complementary perspective. TFP captures efficiency gains from frontier technologies and innovation, but VA reflects how these gains (or losses) are translated into sectoral output growth and structural change. In contexts like Africa, where structural transformation is central to long-term development, VA analysis allows seeing not only whether productivity is rising, but also whether it is associated with the sectoral contribution to the economy. Comparing VA with sectoral TFP is thus critical as it helps to identify whether technology-driven productivity improvements are being reinforced by sectoral growth or undermined by structural bottlenecks that limit output expansion.

At the aggregate level, and as with preliminary analytical findings in chapter 1, agriculture exhibits a statistically significant negative response to frontier technology readiness shocks, with the contraction deepening sharply to around −0.35 to −0.40 percentage points in year 2, before only a partial recovery thereafter, confirming that frontier technology readiness (FTRI) depresses agricultural VA (figure 2.15). This reinforces the sectoral TFP results, where technology and innovation also produced weak or adverse productivity effects.

Figure 2.15 Impulse response functions for change in the FTRI on value added

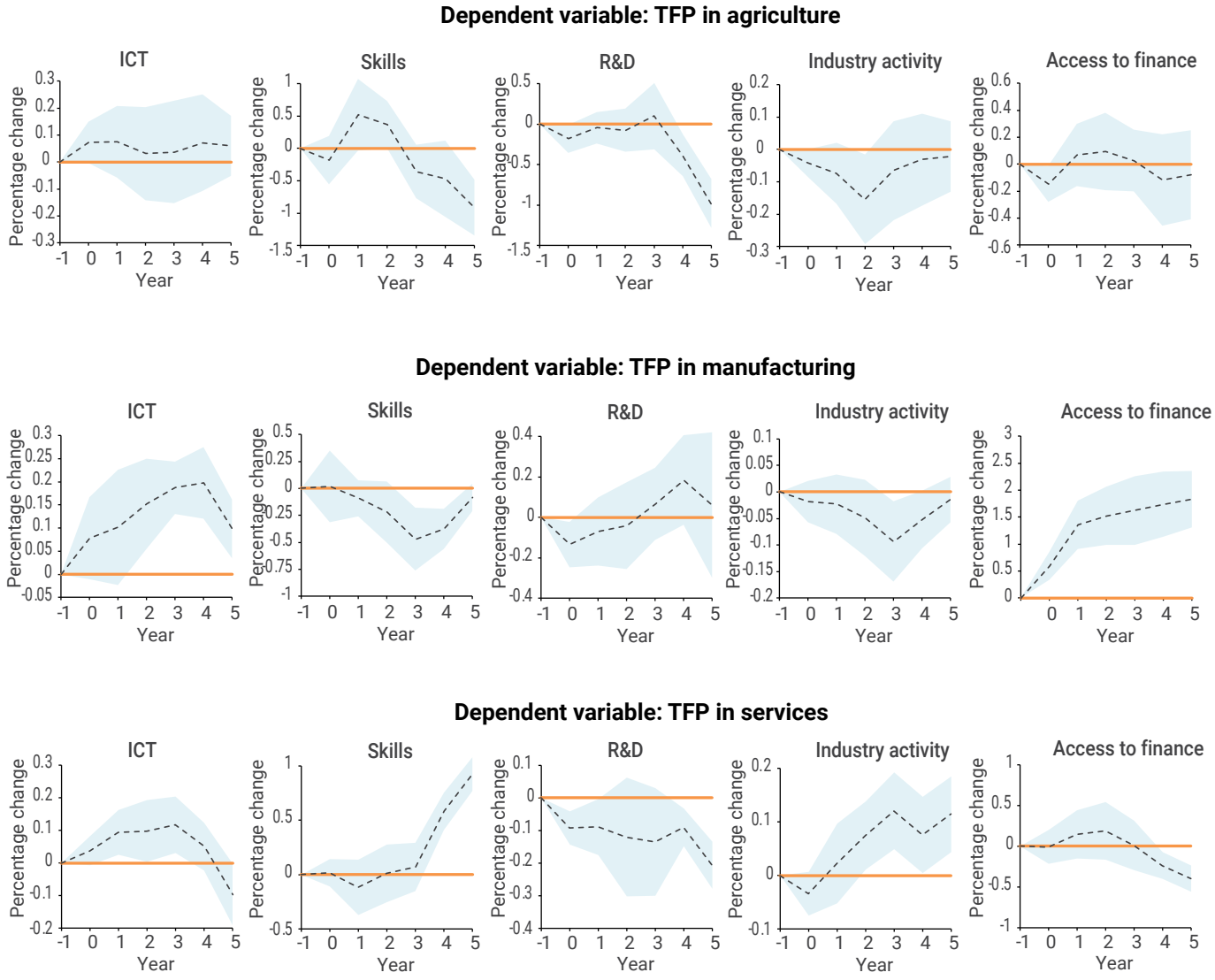


Source: ECA calculations.

When disaggregated into components, the picture becomes clearer. ICT provides some modest short-term benefits through improved access to markets and extension services, but these gains fade quickly (figure 2.16). Skills offer a temporary boost as training helps farmers adopt better practices, yet the lack of sustained institutional support prevents durable improvements. R&D turns negative, reflecting weak agricultural research systems and limited delivery of sector-specific technologies. Finance exacerbates the problem, with credit often unavailable or misallocated, further undermining output.

Agriculture exhibits a statistically significant negative response to frontier technology readiness shocks, with the contraction deepening sharply to around –0.35 to –0.40 percentage points in year 2, before only a partial recovery thereafter, confirming that frontier technology readiness (FTRI) depresses agricultural VA.

Figure 2.16 Impulse response functions for change in the FTRI on value added



Source: ECA calculations.

Together, these effects explain why both TFP and VA in agriculture remain low. Agriculture requires more than incremental innovation inputs. Priority should be given to irrigation, mechanisation, rural infrastructure, and strengthened agricultural R&D. Financing strategies need to be redesigned to channel resources into farm-level innovation and agro-processing. Only with such reforms can frontier technologies and innovation could translate into lasting productivity and value gains.

Manufacturing results reveal a strong and positive elasticity, rising from 0.19 in year 1 to 0.34 percentage points in Year 4, indicating that technology and innovation are consistently associated with higher VA in the sector. This also mirrors the robust productivity gains in TFP, showing that frontier technologies and innovation are being absorbed effectively by industrial systems. When disaggregated, ICT stands out as a key driver, supporting digitalization of production, logistics, and quality control (see figure 2.16). Skills contribute persistently over time, reflecting the growing importance of vocational and technical training. R&D shows a delayed but ultimately positive effect, as industrial research takes time to yield productivity gains. Industry activity reinforces the positive trajectory, with clustering generating spillovers across firms. Most critically, finance emerges as the strongest enabler, with long-term capital access allowing firms to scale and adopt new technologies.

So, manufacturing provides the most fertile ground for structural transformation. Policies should deepen industrial ecosystems, expand access to technology-enhancing finance, and link vocational training to industrial needs. Regional technology corridors under AfCFTA can provide economies of scale, ensuring that productivity and output gains reinforce each other.

In services, technology and innovation effects are found to be positive and statistically significant, peaking at above 0.35 percentage points around year 3, before moderating but remaining positive through year 4. This complements the strong TFP results, underscoring the sector's dynamism in leveraging digitalization. Disaggregated results reveal that ICT deployment is the main channel driving immediate gains in the sector from telecommunications, e-commerce, and financial services (see figure 2.16).

Access to finance plays a critical enabling role by supporting SMEs and platform-based firms before tapering off especially after year 2. Skills become increasingly important after year 3, ensuring that productivity and output gains are sustained as the digital economy expands. R&D remains weak and mostly insignificant, reflecting the sector's reliance on adaptation and diffusion of technologies rather than formal research. Industry activity also contributes positively, as service expansion is closely tied to industrial demand and trade linkages. To consolidate services as a driver of inclusive growth, digitalization must thus be coupled with human capital development and deeper financial systems. Broadband rollout, SME financing, and targeted digital skills training need to be emphasized, to ensure sustained growth and productivity gains.

The VA analysis significantly complements the sectoral productivity analysis—and the narrative on Africa's structural transformation associated with a shift of resources from agriculture to low productivity services. Agriculture remains trapped in structural bottlenecks hindering rapid uptake of technology and innovation, calling for deeper reforms; manufacturing successfully converts technology and innovation efforts into sustained productivity and output growth. That positions it as the anchor for structural transformation. Services thrive on digitalization and finance but require stronger human capital investment to sustain the sector's growth.

This dual perspective from both VA and TFP analysis provide a stronger empirical foundation for designing targeted, sector-specific policies that can accelerate Africa's structural transformation. The analyses reveal that frontier technologies and innovation deliver uneven effects across sectors, so policies need to be sector-specific and component-sensitive, targeting the precise channels—finance in manufacturing, skills in services, and structural reforms in agriculture—that can unlock technology's full potential to enhance structural transformation (box 2.1).

In services, technology and innovation effects are found to be positive and statistically significant, peaking at above 0.35 percentage points around year 3, before moderating but remaining positive through year 4.

Box 2.1 Harnessing frontier technologies for sectoral transformation

Frontier technologies and innovation are transforming Africa's production landscape, but their effects differ sharply across sectors. Converting technology readiness into productivity and growth requires sector-specific enablers and coherent national strategies.

Sectoral channels of impact:

Agriculture
Productivity gains from frontier technologies remain limited due to rainfed farming, low mechanization, weak R&D, and restricted digital access. In some contexts, digital adoption imposes short-term adjustment costs when new practices disrupt traditional production systems.

Manufacturing
The most consistent beneficiary of frontier technologies. Digital automation, industrial clustering, and smart logistics generate scale economies and sustained efficiency gains, underpinning industrial diversification and structural transformation.

Services
Rapid and significant benefits arise from digitalization in telecommunications, fintech, logistics, and e-commerce. Innovation occurs mainly through technology diffusion, adaptation, and new business models rather than formal R&D.

Translating readiness into industrial outcomes

Sector	Policy Priorities
Agriculture	Expand irrigation, mechanization, and agroprocessing; redesign financing to channel resources towards farm-level innovation.
Manufacturing	Deepen industrial ecosystems, strengthen vocational and technical training, and expand access to technology-enhancing finance.
Services	Pair digitalization with financial inclusion and human-capital development, focusing on digital and entrepreneurial skills.

Key complementary enablers:

Skills: Continuous technical and vocational training strengthens absorptive capacity, particularly in manufacturing and services.

Finance: Access to affordable credit is the strongest driver of productivity gains in capital-intensive sectors, while limited agricultural finance remains a binding constraint.

ICT & infrastructure: Broadband expansion and digital connectivity are prerequisites for technology diffusion, especially in rural areas.

R&D & institutions: Industrial R&D produces delayed but positive results; agricultural research systems require revitalization. Strong governance enhances technology absorption in agriculture and industry.

Source: ECA 2025.

In sum, frontier technologies are propelling productivity growth in manufacturing and services, while agriculture remains constrained by structural bottlenecks. Achieving inclusive and sustainable structural transformation requires sector-specific policies that integrate finance, skills, infrastructure, and innovation systems to unlock technology's full potential across Africa's economies

POLICY IMPLICATIONS

Over the past three decades, much of Africa's growth has been driven by labour force expansion and resource use rather than productivity gains, leaving economies vulnerable to external shocks and commodity cycles. With a rapidly growing population, rising urbanization, and mounting climate and debt pressures, the continent cannot rely indefinitely on factor accumulation. Closing the productivity gap through investments in technology and innovation is therefore essential to unlock higher living standards, create decent jobs for its youth, and build resilience in the face of global disruptions. Strengthening skills and industrial capacity, governance, and infrastructure could provide the pathway to shift African economies from fragile, short-term growth to sustainable structural transformation and growth.

This chapter investigated whether frontier technologies and innovation have had a measurable impact on productivity and growth in African economies. The empirical results show that improvements in technological readiness and innovation, measured through the Frontier Technology Readiness Index (FTRI), do not generate immediate productivity gains in productivity and thus growth. Instead, they require a gestation period before producing significant and sustained results. From the second year onwards, the productivity effects of technology adoption become positive, peaking around year 3 and year 4, before stabilizing at a higher level in year 5. This trajectory highlights two important insights. First, policies that strengthen technological capacity should not be expected to yield instant results but should be sustained over the medium term to capture their full benefits. Second, the pattern confirms that technology and innovation adoption in Africa is a gradual process, requiring time for firms, workers, and institutions to adapt before productivity gains materialize.

Disaggregated findings deepen these insights. Industry activity—including high-tech manufacturing, ICT, and digital services—emerge as the most consistent drivers of productivity and growth. Skill development follows a U-shaped trajectory: initially negative due to adjustment costs in training and reallocation, but strongly positive in the medium term, confirming that human capital is an indispensable long-run enabler of technology and innovation utilization. ICT deployment provides short-term boosts, but its benefits plateau unless combined with industrial and skill development. By contrast, R&D and access to finance remain weak or inconsistent contributors, reflecting chronic underinvestment in research and the absence of financial mechanisms that effectively direct resources to productive, technology-intensive activities, extend investment horizons, and support firm-level absorption—conditions essential for finance to translate into sustained growth.

The analysis also highlights that traditional growth drivers such as trade openness and foreign direct investment (FDI) have limited direct effects on productivity in Africa. While trade integration and capital inflows contribute to growth at the aggregate level, they do not automatically enhance efficiency or innovation capacity unless accompanied by policies that strengthen absorptive capacity, governance, and infrastructure. Similarly, the negative or insignificant results for human development indicators suggest that the quality and alignment of education and health outcomes matter more than quantitative improvements alone. In the long term, however, institutional quality becomes a significant enabler, reinforcing the need for governance reforms that can sustain innovation ecosystems.

Agriculture continues to account for a substantial share of employment and value added in many African

economies, yet its productivity remains volatile and, in some cases, negative. The sector struggles to convert frontier technologies and innovation into consistent productivity gains. Although ICT deployment and trade openness offer some benefits, they are undermined by structural vulnerabilities such as climate shocks, credit constraints, and weak R&D capacity. Value-added growth in agriculture has thus come more from expanding labour input than from efficiency improvements. This highlights the pressing need to strengthen agricultural innovation systems, and channel finance to productivity-enhancing technologies such as climate-smart agriculture.

Manufacturing emerges as the strongest and most consistent beneficiary of technological readiness. TFP in the sector rises steadily with technology adoption, indicating robust productivity payoffs. Value added in manufacturing also expands significantly as frontier technologies and innovation are integrated, underlining its potential as a central engine of Africa's structural transformation. ICT adoption, skill development, and access to finance are particularly strong drivers here. However, the negative association of some FDI flows with productivity suggests a risk of enclave-type industrialization, where foreign investment is concentrated in narrow, low-linkage activities. Policies must thus focus on maximizing spillovers and building stronger domestic–foreign linkages.

Services also show clear productivity gains from technology and innovation measures. ICT deployment and access to finance are major enablers, while skills become increasingly important as services become more knowledge-intensive and digitalized. Value added in services has expanded rapidly, especially in finance, logistics, and communications, where digitalization has transformed business models. Yet demographic pressures and uneven human capital development constrain the sector's potential to fully leverage frontier technologies.

Overall, these sectoral patterns reveal divergence. Manufacturing and services are already translating technological readiness into measurable productivity and value-added gains. But agriculture remains trapped in low-productivity growth. This divergence underlines the need for differentiated policy strategies that target sector-specific bottlenecks—supporting industrial upgrading and digital services on the one hand, while building resilience and innovation systems for agriculture on the other. It also reflects a fundamental value-chain gap across sectors. Technological adoption tends to generate stronger and more sustained returns where production systems are embedded in dense, well-coordinated value chains, but remains weak where such linkages are fragmented or underdeveloped.

Recent work by ECA on cross-border agricultural value chains illustrates this challenge clearly. For example, regional livestock value chains in the Horn of Africa and Eastern Africa—linking pastoral production systems in Ethiopia, Kenya, Somalia, and Uganda—show that productivity gains materialize only when technology adoption—such as digital animal traceability, veterinary services, and cold-chain logistics—is accompanied by coordinated investments in cross-border transport corridors, sanitary and phytosanitary standards, and regional market integration.[49] Similarly, cross-border rice and staple crop value chains in West Africa demonstrate that farm-level innovations deliver limited returns in the absence of agro-processing capacity, storage infrastructure, and harmonised trade and quality standards across borders.[50]

These dynamics extend beyond agriculture and point to a broader structural challenge: Africa's technological readiness is not yet fully aligned with its comparative advantage in frontier technology-intensive global value chains, particularly those linked to critical minerals, renewable energy, and green industrialisation. The continent holds a dominant share of global reserves of cobalt, manganese, lithium, bauxite, platinum group metals, and rare earth elements—inputs central to batteries, electric vehicles, renewable power systems, green hydrogen, and digital infrastructure.[51] But as with agriculture, productivity and income gains remain limited where these resources are embedded in extractive, weakly integrated value chains characterized by low domestic processing, limited technological spillovers, and weak linkages to manufacturing and modern services.

Technological readiness delivers significantly higher productivity returns when African economies upgrade within these value chains—moving into mineral beneficiation, battery components, renewable-energy equipment, green hydrogen, and associated logistics

and digital services.[52] Where extraction is combined with reliable renewable energy, regional power pools, efficient transport corridors, and harmonized standards, opportunities for value addition, learning-by-doing, and employment creation expand markedly. As in agriculture, technology alone is insufficient without dense production networks, coordinated infrastructure, and policy-enabled market integration.

Under the African Continental Free Trade Area (AfCFTA), these value-chain bottlenecks are increasingly being addressed through the AfCFTA Guided Trade Initiative and the Action Plan for Boosting Intra-African Trade, which prioritize regional agro-industrial value chains, logistics upgrading, and services that support cross-border production networks. Strengthening such regional value chains—by deepening agroprocessing, harmonizing standards, upgrading transport and digital trade infrastructure, and expanding trade-facilitating services—will thus be critical for transmitting frontier technologies into broad-based productivity gains, employment creation, and structural transformation across African economies.

The AfCFTA also provides a platform to operationalize upgrading in mineral- and energy-based value chains, by enabling the development of regional industrial clusters around critical minerals and clean energy linked through cross-border transport, energy, and digital infrastructure. Strategic use of rules of origin, regional standards, and investment facilitation can further incentivize local processing, supplier development, and skill formation, allowing African firms to internalize larger segments of green and digital value chains.[53]

In this sense, Africa's static comparative advantage in natural endowments can be transformed into a dynamic comparative advantage—anchored not in resource extraction alone, but in technology-enabled, regionally integrated production systems that support sustained productivity growth and long-term structural transformation.

Box 2.2 From more finance to better, targeted, and sequenced finance within financial resource constraints

Expanding access to finance alone is insufficient to generate sustained productivity and growth gains. While financial deepening can support short-term economic activity, its effects weaken over time when financial resources are not effectively channelled to productive, technology-enhancing investments.

As discussed in chapter 1, African economies operate under tight fiscal and debt constraints, which limit the scope for large-scale public financing and increase reliance on domestic financial systems to fund government borrowing. In this context, financial resources are often absorbed by public financing needs or short-term, low-productivity activities, while innovative firms and technology-intensive sectors face persistent financing gaps. Limited firm capabilities and weak linkages between finance and industry further reduce the productivity impact of finance.

The policy priority is therefore not to expand finance indiscriminately, but to improve its quality, allocation and its sequencing within existing fiscal constraints. This requires:

- Directing financial resources to productive and technology-intensive activities.
- Extending investment horizons through long-term and risk-sharing instruments.
- Strengthening firm-level capabilities to translate finance into productivity gains.
- Managing public borrowing in ways that minimize crowding out of private productive investment.

Without these reforms, additional finance risks reinforcing low-productivity growth. But when aligned with fiscal discipline and structural transformation strategies, finance can support technology adoption, productivity growth, and sustainable development.

Source: ECA 2026.

ANNEX 2.1 VARIABLES, DATA, AND SOURCES

Variable name	Measurement	Data source
Capital stock	Constructed via perpetual-inventory method (PIM): $K_t = (1-\delta)K_{t-1} + I_t$ with $\delta = 0.05$ baseline	Authors' computation based on World Bank World Development Indicators (WDI)
Labour	Total employment headcount	ILOSTAT
Dependent variable		
Total factor productivity (TFP)	Residual of a Cobb–Douglas production function with capital and labour inputs (country and year FE); alternatively, Solow residual with capital share parameter, $\alpha = 0.35$	Authors' computation using capital (WDI), labour (ILO), and output (WDI) data
GDP per capita	GDP per capita, constant 2015 US$	World Bank World Development Indicators (WDI)
Independent variable		
Frontier technology readiness index (FTRI)	Composite index of technology adoption and innovation readiness	UNCTAD
Control variables		
Human Development Index (HDI)	Composite index of life expectancy, education, and income	UNDP Human Development Reports
Foreign direct investment (FDI)	Net inflows of foreign direct investment, % of GDP	World Bank World Development Indicators (WDI)
Trade openness	Sum of exports and imports as a percentage of GDP	World Bank World Development Indicators (WDI)
Dependency ratio	Ratio of children (0–14) and elderly (65+) to working-age population (15–64)	Authors' computation based on ILO population data
Precipitation	Annual average precipitation (mm)	Our World in Data (OWID), Copernicus Climate Change Service
Institutional quality index	First principal component from six Worldwide Governance Indicators (Control of Corruption, Government Effectiveness, Rule of Law, Voice and Accountability, Political Stability, Regulatory Quality)	Authors' computation using World Bank Worldwide Governance Indicators (WGI)
Access to electricity	Percentage of population with access to electricity	World Bank World Development Indicators (WDI)
ICT goods imports	ICT goods imports as a percentage of total goods imports	World Bank World Development Indicators (WDI)
Internet access	Percentage of individuals using the internet	World Bank World Development Indicators (WDI)

ANNEX 2.2 EMPIRICAL STRATEGY

To examine how frontier technologies and innovation affect total factor productivity (TFP), the analysis adopts the Local Projection (LP) approach of Jordà (2005), which traces the dynamic response of productivity to changes in technological readiness over time. LPs are well suited to the African context, where technology adoption is gradual, heterogeneous across countries, and characterized by delayed effects rather than discrete policy shocks. Unlike VAR-based methods, LPs do not impose restrictive assumptions on dynamic structure, allowing greater flexibility in capturing medium-term productivity dynamics. This framework is now widely used in applied macroeconomic analysis.[54]

In this setting, frontier-technology readiness is treated as a continuous and cumulative process, reflecting sustained investments in skills, infrastructure, and innovation systems rather than one-off interventions. As LPs are a dynamic estimation technique rather than a causal identification strategy per se, the resulting impulse responses are interpreted as conditional dynamic relationships between technology readiness and productivity, given observed controls, fixed effects, and lagged productivity dynamics. In particular, a one-standard-deviation change in the Frontier Technology Readiness Index (FTRI) should be understood as a shift in underlying readiness conditions driven by incremental policy and investment adjustments, not as a discrete policy shock.

To examine the impact of technology and innovation on productivity, the dependent variable is defined as the change in the logarithm of TFP for each country over a five-year horizon, calculated as $\log(\mathrm{TFP}_{i,t+h}) - \log(\mathrm{TFP}_{i,t-1})$.

The key explanatory variables encompass FTRI and its components which include ICT deployment, labour skills, R&D capacity, industrial development, and financial depth, to a greater extent capturing both technological and innovative developments among countries.[55] To account for persistence in productivity dynamics, the first two lags of TFP are included. In addition, the model controls for FDI, human development, trade openness, the dependency ratio, total precipitation, and institutional quality. The baseline LP model is therefore specified as:

$$\log(\mathrm{TFP}_{i,t+h}) - \log(\mathrm{TFP}_{i,t-1}) = \alpha_{i,h} + \gamma_{t,h} + \sum_{k=1}^{2} \phi_{k,h} \log(\mathrm{TFP}_{i,t-k}) + \beta_h \mathrm{TI}_{i,t} + \delta_h \mathrm{X}_{i,t} + \varepsilon_{i,t+h}, h = 0, 1, \ldots, 5 (1)$$

In this specification, $\alpha_{i,h}$ denotes country fixed effects, capturing time-invariant heterogeneity across countries, while $\gamma_{t,h}$ represents time fixed effects, accounting for global or regional shocks common to all economies in a given period. The key parameter of interest β_h, measures the dynamic effect of frontier technologies and innovation on TFP at horizon h, while δ_h captures those of the control variables. The error term $\varepsilon_{i,t+h}$ is specified to be robust to heteroskedasticity, autocorrelation, and cross-sectional dependence.

Estimating the model sequentially across horizons allows the analysis to trace medium-term productivity responses to changes in technology readiness.

Because the FTRI is a slow-moving composite index, a "one-standard-deviation change" should not be interpreted as a discrete policy shock. Instead, it is best understood as a shift in readiness conditions reflecting cumulative policy and investment adjustments (e.g., incremental improvements in ICT deployment, skills, industrial activity), after conditioning on observed covariates, country fixed effects, and common time shocks.

A central empirical challenge is that frontier-technology readiness is not exogenous. Adoption and readiness evolve jointly with economic performance and institutional capacity, giving rise to several identification risks: (i) dynamic panel bias due to persistent productivity; (ii) reverse causality, whereby higher productivity enables greater investment in technology and skills; (iii) anticipation effects, as governments may scale up readiness in expectation of future growth; and (iv) cross-sectional dependence driven by common global shocks. Ignoring these issues would weaken inference.

Of these concerns, reverse causality and dynamic panel bias are explicitly addressed by implementing Local Projections combined with System GMM (LP–SGMM). In this specification, both lagged productivity and frontier-technology readiness are treated as endogenous and instrumented using restricted, collapsed internal lags, while controlling for country fixed effects and common time shocks. LP–SGMM therefore allows us to assess whether the estimated dynamic productivity responses remain robust once feedback effects from productivity to technology readiness are taken into account. Given the relatively small cross-section, LP–SGMM is used conservatively as a robustness and sensitivity check, rather than as the sole basis for causal claims.

LP–SGMM implementation details

Given the relatively small cross-section (around 47 countries), LP–SGMM is implemented conservatively and treated as a robustness and sensitivity check rather than the primary basis for causal claims. Instrument proliferation is limited through the use of collapsed instrument matrices and restricted lag windows, fully documented and consistent with the replication code. Specifically, lagged TFP is instrumented using GMM-style lags starting at t–2, while the FTRI is instrumented using only short lag ranges (t–2 to t–3). Control variables enter as standard IV-style regressors alongside time dummies.

Standard diagnostic tests (instrument count, Hansen test, and AR(2) test) are reported. While the Hansen test does not reject the null of instrument validity, its power may be limited in small samples with instrument counts close to the number of groups. Accordingly, the LP–SGMM results are interpreted with caution and used to assess whether the estimated dynamic responses are sensitive to correcting for reverse causality and persistence, rather than as definitive causal estimates.

To further assess robustness under alternative identifying assumptions, the analysis complements LP–SGMM with two additional estimators. Local Projections with fixed effects and Driscoll–Kraay standard errors (LP–FE–DK) provide baseline dynamic associations that are robust to serial correlation, heteroskedasticity, and cross-sectional dependence, but do not resolve reverse causality. Local Projections combined with entropy balancing for continuous treatments (LP–EBCT) reduce bias from non-random selection into technology adoption by ensuring comparability across countries on observable characteristics.

Overall, the triangulation across LP–FE–DK, LP–EBCT, and LP–SGMM provides a transparent and robust framework for inference. The consistency of results across estimators—despite their different identifying assumptions—supports the conclusion that frontier-technology readiness is systematically associated with medium-term productivity dynamics in Africa. At the same time, the analysis remains explicit about its limits: the estimated impulse responses should be interpreted as conditional dynamic relationships, not as policy-invariant causal parameters.

Data

The data used combine multiple international sources spanning up to 54 African countries covering more than five decades (1970–2024). For the purposes of this empirical specification, a reduced sample of 47 countries covering the period 1992–2024, after removing pre-1992 observations were used[56] This restriction is driven by data availability for key variables to satisfy the requirements of panel estimation. Moreover, because the Frontier Technology Readiness Index (FTRI) is available only from 2013–2024, the final dataset takes the form of an unbalanced panel, combining longer-run macroeconomic and structural indicators with more recent measures of technological capability. The derivation of total factor productivity (TFP) relies on measures of capital and labour, based on Solow's growth accounting framework.[57] Capital stock is constructed using a Penn World Table-based perpetual-inventory method (PIM), updated through 2023 using gross capital formation series from the World Development Indicators.[58] The Penn World Table methodology was extended beyond 2019 through in-house computations. Labour input is measured as employment headcounts from ILO modelled estimates,[59] which provide long time series across African economies is extended.[60]

The key proxy for innovation and technology adoption is the Frontier Technology Readiness (FTR) Index, developed by UNCTAD.[61] The index aggregates five interconnected dimensions of technology and innovation related variables: ICT deployment, R&D investment, skills capacity, access to finance, and industrial activity. The choice of the FTRI is justified on both conceptual and empirical grounds. Conceptually, it reflects the inherently multidimensional character of technological readiness and innovation capacity.[62] Empirically, it provides a harmonized, cross-country measure that is standardized, comparable, and policy-relevant, thereby enabling systematic evaluation of readiness levels across countries and over time,[63] providing a good basis for assessing the impact of technology and innovation on African economies.

The selection of dependent and independent variables therefore reflects a deliberate effort to operationalize the pathways through which innovation and technology adoption contribute to economic growth. The analysis also incorporates a set of macroeconomic control variables, selected on the basis of both theoretical considerations and empirical evidence from the innovation–growth literature. These covariates are drawn from the World Bank's World Development Indicators including FDI inflows, gross capital formation, trade openness (trade in goods and services as a share of GDP), real GDP.[64] The Human Development Index (HDI) is obtained from the UNDP Human Development Reports,[65] while climatic data on precipitation are taken from Our World in Data, based on the Copernicus Climate Change Service.[66] This is relevant since most of the African economies are agriculture dependent, having an impact on agricultural productivity and growth. The dependency ratio is constructed by the authors following UN methodology, using population and employment data from ILO. The rationale here is that a large non-working share of the population could be a demographic burden which could negatively affect productivity growth. Institutional quality is proxied by a composite index derived through principal component analysis of the six Worldwide Governance Indicators, with the first principal component explaining approximately 80 per cent of the variance across governance dimensions.[67]

Variable construction

The dependent variable $\ln \widehat{\mathrm{A^{FE}}}_{i,t}$, is defined as the Solow residual using the fixed-effects approach. In our estimates, the capital share parameter is derived from the data, yielding $\hat{a} = 0.28$. Lags and leads of this measure $\left(\ln \widehat{\mathrm{A^{FE}}}_{i,t}, \ldots, \ln \widehat{\mathrm{A^{FE}}}_{i,t+5}\right)$ are generated for the local projection framework.

Key explanatory variables include the Frontier Technology Readiness Index and its components, which capture technological and innovation related activities in African countries including ICT deployment (infrastructure availability and quality), skills (education and labour-market capabilities), R&D activities (publications and patents in 17 frontier technology areas), industry activity (high-tech manufacturing, ICT, and digital services), and access to finance (domestic credit to the private sector). Control variables consist of the composite institutional quality index, foreign direct investment (FDI) inflows, HDI, trade openness, dependency ratio, and precipitation. Additional covariates used in the entropy balancing step include real GDP per capita, access to electricity, access to internet and ICT goods imports.

Sample selection

The working panel consists of 47 countries observed over 32 years (1992–2023), with a maximum of about 1,177 observations. The estimation samples range between 400 and 650 observations, depending on the specific lag and lead structures. The panel is unbalanced, reflecting missing data for selected countries and variables. To account for zero and negative values, an inverse hyperbolic sine (asinh) transformation to FDI and inflation is applied. Variables strictly positive by construction (HDI, trade, dependency ratio, precipitation) are transformed using natural logarithms. Missing data points are excluded listwise, and estimation samples are constructed accordingly. The minimum sample size across specifications remains above 400 observations, ensuring adequate coverage.

ANNEX 2.3 IMPACT OF TECHNOLOGY AND INNOVATION (FTRI) ON TFP USING LP-SGMM

Frontier Technology Readiness Index	**-0.025**	**0.115***	**0.275****	**0.338*****	**0.339*****	**0.262*****
	(0.070)	**(0.063)**	**(0.111)**	**(0.106)**	**(0.085)**	**(0.094)**
L.Total factor productivity	1.158***	1.050***	1.288***	0.999***	1.145***	1.168***
	(0.100)	(0.146)	(0.319)	(0.316)	(0.269)	(0.296)
L2.Total factor productivity	-0.038	-0.079	-0.267	0.033	-0.182	-0.315
	(0.157)	(0.143)	(0.404)	(0.441)	(0.324)	(0.315)
L.FDI ratio to GDP	-0.001	-0.000	-0.000	-0.001	-0.001	-0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
L.Human Development Index, log	-0.053**	-0.139**	-0.207**	-0.276**	-0.324*	-0.356**
	(0.023)	(0.057)	(0.096)	(0.129)	(0.165)	(0.172)
L.Trade ratio of GDP	0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
L.Dependency ratio	-0.000	-0.000	-0.000	-0.000	-0.001	-0.001
	(0.000)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
L.Total precipitation, log	0.002	0.006	0.006	0.005	0.000	-0.001
	(0.004)	(0.009)	(0.009)	(0.011)	(0.012)	(0.014)
I. Institutional quality index	0.002	0.006	0.002	0.005	0.008	0.019*
	(0.003)	(0.005)	(0.006)	(0.008)	(0.009)	(0.011)
N	618	572	525	479	434	389
Groups	47	47	47	46	46	46
Number of instruments	43	41	39	37	35	33
Hansen p	0.551	0.517	0.279	0.300	0.244	0.215
AR(2) p	0.298	0.018	0.155	0.329	0.459	0.598

Note: *** p<0.01, ** p<0.05, * p<0.1
Source: Results of the empirical study, authors, 2025.

ANNEX 2.4 IMPACT OF TECHNOLOGY AND INNOVATION (FTRI) ON PER CAPITA GROWTH USING LP-SGMM

	Year (0)	Year (1)	Year (2)	Year (3)	Year (4)	Year (5)
Frontier Technology Readiness Index	**0.013**	**-0.165**	**-0.013**	**0.097**	**0.111**	**0.301****
	(0.082)	**(0.141)**	**(0.149)**	**(0.141)**	**(0.112)**	**(0.093)**
L.GDP per capita, log	1.277***	1.133***	1.082***	0.946***	0.842***	0.638***
	(0.109)	(0.119)	(0.140)	(0.119)	(0.148)	(0.122)
L2.GDP per capita, log	-0.379***	-0.328**	-0.319*	-0.318**	-0.367***	-0.263***
	(0.108)	(0.138)	(0.146)	(0.111)	(0.096)	(0.058)
L.FDI ratio to GDP	-0.001*	-0.001**	-0.001	-0.001	-0.001	-0.002**
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
L.Human Development Index, log	-0.170	-0.495***	-0.926***	-0.948***	-1.030***	-1.479***
	(0.113)	(0.135)	(0.113)	(0.122)	(0.197)	(0.134)
L.Trade ratio of GDP	0.001*	0.001***	0.001***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L.Dependency ratio	-0.005***	-0.008***	-0.008***	-0.009***	-0.011***	-0.008***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
L.Total precipitation, log	-0.017	-0.001	-0.003	0.013	0.009	-0.007
	(0.025)	(0.019)	(0.017)	(0.010)	(0.010)	(0.010)
I. Institutional quality index	0.017***	0.035***	0.043***	0.054***	0.068***	0.082***
	(0.005)	(0.005)	(0.009)	(0.011)	(0.012)	(0.010)
N	429	429	429	414	386	355
Groups	41	41	41	41	41	41
R-squared	0.939	0.874	0.830	0.799	0.768	0.780

Note: *** p<0.01, ** p<0.05, * p<0.1
Source: Results of the empirical study, authors, 2025.

REFERENCES

Aali Bujari, A., and F. Venegas Martínez. 2016. "Technological Innovation and Economic Growth in Latin America." *REMEF (Revista Mexicana de Economía y Finanzas)* 11 (2): 77–89.

Abramovitz, M. 1986. "Catching Up, Forging Ahead, and Falling Behind." *Journal of Economic History* 46 (2): 385–406.

Acemoglu, D., P. Aghion, and F. Zilibotti. 2006. "Distance to Frontier, Selection, and Economic Growth." *Journal of the European Economic Association* 4 (1): 37–74.

Acemoglu, D., S. Johnson, and J. A. Robinson. 2005. "Institutions as the Fundamental Cause of Long-Run Growth." In *Handbook of Economic Growth, Volume 1A*, edited by P. Aghion and S. Durlauf, 385–472. Elsevier.

Acemoglu, D., and S. Johnson. 2007. "Disease and Development: The Effect of Life Expectancy on Economic Growth." *Journal of Political Economy* 115 (6): 925–985.

Adejumo, O. O., A. V. Adejumo, and T. A. Aladesanmi. 2020. "Technology-Driven Growth and Inclusive Growth: Implications for Sustainable Development in Africa." *Technology in Society* 63: 101373. https://doi.org/10.1016/j.techsoc.2020.101373.

AfCFTA Secretariat (African Continental Free Trade Area Secretariat). 2023. *AfCFTA Guided Trade Initiative: Progress Report*. AfCFTA Secretariat, Accra.

Aghion, P., and P. Howitt. 1990. "A Model of Growth Through Creative Destruction." NBER Working Paper 3223, National Bureau of Economic Research, Cambridge, MA.

Aghion, P., and P. Howitt. 1998. *Endogenous Growth Theory*. MIT Press, Cambridge, MA.

Ahmed, E. M., and R. Ridzuan. 2013. "The Impact of ICT on East Asian Economic Growth: Panel Estimation Approach." *Journal of the Knowledge Economy* 4 (4): 540–555.

Alesina, A., D. Furceri, J. D. Ostry, C. Papageorgiou, and D. P. Quinn. 2024. "Structural Reforms and Elections: Evidence from a Worldwide New Dataset." *Journal of the European Economic Association* 22 (4): 1936–1980.

Alfaro, L., A. Chanda, S. Kalemli-Ozcan, and S. Sayek. 2010. "Does Foreign Direct Investment Promote Growth? Exploring the Role of Financial Markets on Linkages." *Journal of Development Economics* 91 (2): 242–256.

Anakpo, G., and A. Oyenubi. 2022. "Innovation and Economic Growth in Southern Africa: Evidence from Patent and R&D Indicators." *African Journal of Economic and Management Studies* 13 (3): 451–470.

Archibugi, D., and A. Coco. 2005. "Measuring Technological Capabilities at the Country Level: A Survey and a Menu for Choice." *Research Policy* 34 (2): 175–194.

Arellano, M., and O. Bover. 1995. "Another Look at the Instrumental Variable Estimation of Error-Components Models." *Journal of Econometrics* 68 (1): 29–51.

Bekana, D. M. 2020. "Institutions, Innovation, and Economic Growth in Africa." *Journal of African Business* 21 (4): 495–516.

Bilbao-Osorio, B., and A. Rodríguez-Pose. 2004. "From R&D to Innovation and Economic Growth in the EU." *Growth and Change* 35 (4): 434–455.

Bloom, N., R. Sadun, and J. Van Reenen. 2012a. "Americans Do IT Better: US Multinationals and the Productivity Miracle." *American Economic Review* 102 (1): 167–201.

Bloom, N., R. Sadun, and J. Van Reenen. 2012b. "The Organization of Firms Across Countries." *Quarterly Journal of Economics* 127 (4): 1663–1705.

Blundell, R., and S. Bond. 1998. "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models." *Journal of Econometrics* 87 (1): 115–143.

Bomprezzi, P., S. Marchesi, and R. Turk-Ariss. 2022. "Do IMF Programs Stimulate Private Sector Investment?" IMF Working Paper WP/22/157, International Monetary Fund, Washington, DC.

Borensztein, E., J. De Gregorio, and J.-W. Lee. 1998. "How Does Foreign Direct Investment Affect Economic Growth?" *Journal of International Economics* 45 (1): 115–135.

Campos, N. 2010. "The Impact of Information and Communication Technologies on Economic Growth in Latin America in Comparative Perspective." In *Innovation and Economic Development: The Impact of Information and Communication Technologies in Latin America,* 139–158. https://doi.org/10.4337/9781849806558.00012.

Çetin, M. 2013. "Innovation and Economic Growth: Panel Cointegration and Causality Analysis for European Union Transition Economies." *Journal of Economic Cooperation and Development* 34 (2): 1–28.

Cirera, X., and W. Maloney. 2017. *The Innovation Paradox: Developing-Country Capabilities and the Unrealized Promise of Technological Catch-Up*. World Bank, Washington, DC.

Comin, D. 2006. "Total Factor Productivity." In *The New Palgrave Dictionary of Economics*, 2nd ed.

Das, G. G., and I. Drine. 2020. "Distance from the Technology Frontier: How Could Africa Catch Up via Socio-Institutional Factors and Human Capital?" *Technological Forecasting and Social Change* 150: 119755. https://doi.org/10.1016/j.techfore.2019.119755.

Dempere, J. M., E. Garcés, and L. Gutierrez. 2023. "National Innovation Ecosystems and Economic Growth: A Global Panel Data Analysis." *Technological Forecasting and Social Change* 191: 122532.

Dosi, G. 1988. "Sources, Procedures, and Microeconomic Effects of Innovation." *Journal of Economic Literature* 26 (3): 1120–1171.

Driscoll, J. C., and A. C. Kraay. 1998. "Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data." *Review of Economics and Statistics* 80 (4): 549–560.

ECA (United Nations Economic Commission for Africa). 2023. *Is Africa Having Potential for Regional Value Chains?* ECA, Addis Ababa.

ECA (United Nations Economic Commission for Africa). 2024a. *Rapport sur l'État de la Diversification Économique en Afrique Centrale 2024: Mise en Œuvre Rapide des Solutions de Recherche et d'Innovation pour Accélérer la Diversification Économique en Afrique Centrale*. ECA, Addis Ababa.

ECA (United Nations Economic Commission for Africa). 2024b. *Technological Transformation and Innovation in African Livestock Value Chains*. Africa Business Forum Background Paper. ECA, Addis Ababa.

ECA (United Nations Economic Commission for Africa). 2025. *Regional Value Chains and Industrialization under the AfCFTA*. Africa Business Forum Report. ECA, Addis Ababa.

ECA (United Nations Economic Commission for Africa). 2026. *Growth through Innovation: Harnessing Data and Frontier Technologies for Africa's Economic Transformation.* Economic Report on Africa 2026. Forthcoming. Addis Ababa.

Fagerberg, J., M. Srholec, and B. Verspagen. 2010. "Innovation and Economic Development." In *Handbook of the Economics of Innovation*, edited by B. Hall and N. Rosenberg. North-Holland.

Faisal, S. 2022. "Analysis of Human Development, Economic Growth and Income Inequality in SAARC Country." *Journal of Development and Social Sciences* 3 (2): 96–104.

Farole, T., and D. Winkler. 2014. *Making Foreign Direct Investment Work for Sub-Saharan Africa: Local Spillovers and Competitiveness in Global Value Chains*. World Bank, Washington, DC.

Feenstra, R. C., R. Inklaar, and M. P. Timmer. 2015. "The Next Generation of the Penn World Table." *American Economic Review* 105 (10): 3150–3182.

Filippi, E., M. Bannò, and S. Trento. 2023. "Automation Technologies and Their Impact on Employment: A Review, Synthesis and Future Research Agenda." *Technological Forecasting and Social Change* 191: 122448.

Forson, J. A., P. Buracom, G. Chen, and T. Y. Baah-Ennumh. 2021. "Institutional Quality, Innovation and Economic Growth in Africa." *Economic Change and Restructuring* 54 (2): 191–219.

Gao, J., G. Hua, and B. Huo. 2024. "Digital Technology, Green Innovation, and High-Quality Economic Development: Mechanism Analysis and Empirical Evidence." Journal of the Knowledge Economy 16: 12011–12047. https://doi.org/10.1007/s13132-024-02355-4.

Gonzales, C. 2023. "Frontier Technologies, Innovation Quality and Growth: Evidence from AI Patents." *Research Policy* 52 (3): 104715.

Hall, B. H., and B. Khan. 2003. "Adoption of New Technology." NBER Working Paper 9730, National Bureau of Economic Research, Cambridge, MA.

Hanushek, E. A., and L. Woessmann. 2012. "Do Better Schools Lead to More Growth? Cognitive Skills, Economic Outcomes, and Causation." *Journal of Economic Growth* 17 (4): 267–321.

Hasan, I., and C. L. Tucci. 2010. "The Innovation–Economic Growth Nexus: Global Evidence." *Research Policy* 39 (10): 1264–1276.

Hofman, A., C. Aravena, and V. Aliaga. 2016. "Information and Communication Technologies and Their Impact on the Economic Growth of Latin America, 1990–2013." *Telecommunications Policy* 40 (5): 485–501. https://doi.org/10.1016/j.telpol.2016.02.002.

Hulten, C. R. 2001. "Total Factor Productivity: A Short Biography." In *New Developments in Productivity Analysis,* edited by C. R. Hulten, E. R. Dean, and M. J. Harper, 1–52. Studies in Income and Wealth, vol. 63. University of Chicago Press, Chicago. https://doi.org/10.7208/chicago/9780226360645.003.0001.

IEA (International Energy Agency). 2023. *Unlocking Smart Grid Opportunities in Emerging Markets and Developing Economies.* IEA, Paris. https://www.iea.org/reports/unlocking-smart-grid-opportunities-in-emerging-markets-and-developing-economies.

ILO (International Labour Organization). 2024. *ILOSTAT Database.* ILO, Geneva.

IMF (International Monetary Fund). 2004. *World Economic Outlook: Advancing Structural Reforms*. IMF, Washington, DC.

IMF (International Monetary Fund). 2025. *World Economic Outlook Database: October 2025.* IMF, Washington, DC. Accessed December 9, 2025. https://data.imf.org/en/Data-Explorer?datasetUrn=IMF.RES:WEO(9.0.0).

Jammeh, M. 2022. "Technological Innovation and Economic Growth in ECOWAS Countries." *African Development Review* 34 (2): 246–260.

Jordà, Ò. 2005. "Estimation and Inference of Impulse Responses by Local Projections." *American Economic Review* 95 (1): 161–182.

Jordà, Ò., and A. M. Taylor. 2016. "The Time for Austerity: Estimating the Average Treatment Effect of Fiscal Policy." *Economic Journal* 126 (590): 219–255.

Kasongo, A., and T. Makamu. 2024. "Innovation and Economic Growth: An Empirical Analysis for African Countries." *African Journal of Science, Technology, Innovation and Development* 16 (6): 751–760.

Kaufmann, D., A. Kraay, and M. Mastruzzi. 2010. "The Worldwide Governance Indicators: Methodology and Analytical Issues." World Bank Policy Research Working Paper 5430, World Bank, Washington, DC.

Kemgou Voptia, B. E., and Y. Stukalina. 2025a. "Digital Transformation and Quality of Institutions in Sub-Saharan Africa." In *Reliability and Statistics in Transportation and Communication: Human Sustainability and Resilience in the Digital Age,* edited by I. Kabashkin, I. Yatskiv, and O. Prentkovskis. Lecture Notes in Networks and Systems, vol. 1337. Springer, Cham. https://doi.org/10.1007/978-3-031-87532-8_24.

Kemgou Voptia, E. B., and Y. Stukalina. 2025b. "Financial Inclusion in Sub-Saharan Africa: The Case of Mobile Money." *Ekonomika* 103: 81–96.

Kraemer-Mbula, E., G. Sheikheldin, and R. Karimanzira. 2021. "Southern Africa." In *UNESCO Science Report: The Race Against Time for Smarter Development,* edited by S. Schneegans, T. Straza, and J. Lewis. UNESCO Publishing, Paris.

Kurniawati, M. A. 2022. "Analysis of the Impact of Information Communication Technology on Economic Growth: Empirical Evidence from Asian Countries." *Journal of Asian Business and Economic Studies* 29 (1): 2–18.

Law, S. H., L. Ting, and A. M. Kutan. 2020. "Patent Quality, Foreign Spillovers and Economic Growth in Middle-Income Countries: The Case of Malaysia." *World Development* 128: 104841.

Lucas, R. E. 1988. "On the Mechanics of Economic Development." *Journal of Monetary Economics* 22 (1): 3–42.

Maradana, R. P., R. P. Pradhan, S. Dash, M. B. Arvin, N. Bahmani, and J. H. Hall. 2017. "Does Innovation Promote Economic Growth? Evidence from European Countries." *Journal of Innovation and Entrepreneurship* 6 (1): 1–23.

Maradana, R. P., R. P. Pradhan, S. Dash, M. B. Arvin, N. Bahmani, and J. H. Hall. 2019. "Innovation and Economic Growth in European Economic Area Countries: Panel VAR Approach." *Applied Economics Letters* 26 (20): 1737–1741.

McMillan, M., D. Rodrik, and I. Verduzco-Gallo. 2014. "Globalization, Structural Change, and Productivity Growth, with an Update on Africa." *World Development* 63: 11–32.

Mhaka, S., and L. Taonezvi. 2024. "Does Digitalization Increase Economic Growth? Evidence from SADC Countries." *Managing Global Transitions* 22: 201–229.

Mohamed, A., K. Ali, and M. Hassan. 2022. "Innovation and Economic Growth in Developing Economies: Evidence from Panel GMM and ECM Analyses." *Economic Modelling* 111: 105860.

Mothobi, O., and K. Kebotsamang. 2024. "The Impact of Network Coverage on Adoption of Fintech and Financial Inclusion in Sub-Saharan Africa." *Journal of Economic Structures* 13 (1): 1–19.

Nelson, R., and H. Pack. 1999. "The Asian Miracle and Modern Growth Theory." *Economic Journal* 109 (457): 416–436.

Nelson, R. R., and S. G. Winter. 1982. *An Evolutionary Theory of Economic Change*. Harvard University Press, Cambridge, MA.

North, D. C. 1990. *Institutions, Institutional Change and Economic Performance*. Cambridge University Press, Cambridge, MA.

OECD (Organisation for Economic Co-operation and Development). 2009. *Measuring Capital: OECD Manual 2009*. 2nd ed. OECD Publishing, Paris.

OECD/Eurostat (Organisation for Economic Co-operation and Development/Statistical Office of the European Union). 2018. *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation*. 4th ed. OECD Publishing, Paris.

Ofori, I. K., and S. A. Asongu. 2021. "ICT Diffusion, Foreign Direct Investment and Inclusive Growth in Sub-Saharan Africa." Working Paper 21/029, African Governance and Development Institute, Yaoundé.

Ofori, I. K., E. Y. Gbolonyo, and A. Vezzulli. 2025. "Heterogeneous Effects of Frontier Technology Adoption on Economic Growth in Africa." *Structural Change and Economic Dynamics* 75: 526–540.

Okumu, I. M., L. Borghans, and B. ter Weel. 2019. "Innovation and Employment Growth in Africa: Firm-Level Evidence." *Industrial and Corporate Change* 28 (5): 1135–1156.

Oluwatobi, S. O., U. R. Efobi, I. O. Olurinola, and P. O. Alege. 2015. "Innovation in Africa: Why Institutions Matter." *South African Journal of Economics* 83 (3): 390–410.

Otekunrin, A. O., O. O. Fagbohun, and O. B. Bello. 2021. "Financial Innovation, Financial Inclusion and Economic Growth in Africa." *Cogent Economics & Finance* 9 (1): 1880664.

Ouedraogo, N. S., and J. M. M. Kilolo. 2024. "Africa's Critical Minerals Can Power the Global Low-Carbon Transition." *Progress in Energy* 6 (3): 033004.

Pradhan, R. P., M. B. Arvin, J. H. Hall, and M. Nair. 2020. "Innovation, Financial Development and Economic Growth in the Eurozone: Panel VAR Evidence." *Technological Forecasting and Social Change* 161: 120307.

Pritchett, L. 2001. "Where Has All the Education Gone?" *World Bank Economic Review* 15 (3): 367–391.

Qamruzzaman, M., and W. Jianguo. 2017. "Financial Innovation and Economic Growth in Bangladesh." *Financial Innovation* 3 (1): 1–24.

Ritchie, H., P. Rosado, and V. Samborska. 2024. "Climate Change." *Our World in Data*.

Rodrik, D. 2016. "Premature Deindustrialization." *Journal of Economic Growth* 21 (1): 1–33.

Romer, P. M. 1989. "Endogenous Technological Change." *Journal of Political Economy* 98 (5, Part 2): S71–S102.

Romer, P. M. 1990. "Endogenous Technological Change." *Journal of Political Economy* 98 (5, Part 2): S71–S102.

Saba, C. S., O. O. David, and T. P. Voto. 2024. "Institutional Quality Effect of ICT Penetration: Global and Regional Perspectives." *South African Journal of Economic and Management Sciences* 27 (1): a5180. https://doi.org/10.4102/sajems.v27i1.5180.

Scherer, F. M. 2002. "Introduction to Schumpeter and the Endogeneity of Technological Change." In *The Elgar Companion to Neo-Schumpeterian Economics*, edited by H. Hanusch and A. Pyka, 81–89. Edward Elgar.

Schumpeter, J. A. 1934. *The Theory of Economic Development*. Harvard University Press, Cambridge, MA.

Schumpeter, J. A. 1942. *Capitalism, Socialism and Democracy*. Harper & Brothers, New York.

Shukla, R. 2017. "Innovation and Economic Growth in India: Paradox and Prospects." *Indian Economic Journal* 65 (2): 123–140.

Solomon, E. M., and A. van Klyton. 2020. "The Impact of Digital Technology Usage on Economic Growth in Africa." *Utilities Policy* 67.

Solow, R. M. 1956. "A Contribution to the Theory of Economic Growth." *Quarterly Journal of Economics* 70 (1): 65–94.

Solow, R. M. 1957. "Technical Change and the Aggregate Production Function." *Review of Economics and Statistics* 39 (3): 312–320.

Songwe, V. 2020. "The Role of Digitalization in the Decade of Action for Africa." UNCTAD News, September 7. https://unctad.org/news/role-digitalization-decade-action-africa.

Suri, T. 2011. "Selection and Comparative Advantage in Technology Adoption." *Econometrica* 79 (1): 159–209.

Syverson, C. 2011. "What Determines Productivity?" *Journal of Economic Literature* 49 (2): 326–365.

Thi Thi, D. M., and T. P. Do. 2024. "The Interrelationships between Economic Growth and Innovation: International Evidence." *Journal of Applied Economics* 27 (1). https://doi.org/10.1080/15140326.2024.2332975.

Tübbicke, S. 2022. "Entropy Balancing for Continuous Treatments." *Journal of Econometric Methods* 11 (1): 71–89.

Udvari, B., and I. K. Ampah. 2018. "Foreign Aid, Education, and Innovation in Africa." *Hungarian Journal of African Studies* 12 (3): 45–64.

UNCTAD (United Nations Conference on Trade and Development). 2021a. *Commodities and Development Report 2021: Escaping from the Commodity Dependence Trap through Technology and Innovation.* UNCTAD, Geneva.

UNCTAD (United Nations Conference on Trade and Development). 2021b. *Technology and Innovation Report 2021: Catching Technological Waves*. UNCTAD, Geneva.

UNCTAD (United Nations Conference on Trade and Development). 2024. *Frontier Technology Readiness Index*. UNCTAD, Geneva.

UNDP (United Nations Development Programme). 2024. *Human Development Reports*. UNDP, New York.

Wang, T. Y., and S. C. Chien. 2007. "The Influences of Technology Development on Economic Performance—The Example of ASEAN Countries." *Technovation* 27 (8): 471–488.

WIPO (World Intellectual Property Organization). 2022. *IP Facts and Figures 2022.* WIPO, Geneva. https://doi.org/10.34667/tind.47183.

WIPO (World Intellectual Property Organization). 2023. *World Intellectual Property Indicators 2023.* WIPO, Geneva. https://doi.org/10.34667/tind.48541.

WIPO (World Intellectual Property Organization). 2024a. *Global Innovation Index 2024: Unlocking the Promise of Social Entrepreneurship.* WIPO, Geneva. https://doi.org/10.34667/tind.50062.

WIPO (World Intellectual Property Organization). 2024b. *Global Innovation Index 2025: Innovation at a Crossroads.* WIPO, Geneva. https://doi.org/10.34667/tind.58864.

World Bank. 2023. *World Development Indicators.* World Bank, Washington, DC.

World Bank. 2024a. *World Development Indicators*. World Bank, Washington, DC.

World Bank. 2024b. *Worldwide Governance Indicators: 2024 Update*. World Bank, Washington, DC.

World Economic Forum. 2023. "Innovative Approaches for Unlocking R&D Funding in Africa." World Economic Forum, November. https://www.weforum.org/stories/2023/11/innovative-approaches-for-unlocking-research-and-development-funding-in-africa/.

Xie, J., X. Xi, B. Xi, C. Miao, R. Yu, R. Xiang, and F. Hu. 2024. "Frontier Technology Readiness and Green Structural Transformation." *Technological Forecasting and Social Change* 198: 122–138.

ENDNOTES

1 Scherer 2002.

2 Nelson and Winter 1982; Dosi 1988; Romer 1990.

3 Schumpeter 1942; OECD/Eurostat 2018.

4 The FTRI measures a country's ability to adopt, adapt, and use frontier technologies. It draws on indicators of ICT penetration, R&D investment, skills, access to finance, and industry activity, with weights derived from Principal Component Analysis. The index captures three key dimensions of technological transition: Use/Readiness (infrastructure, knowledge, and basic skills that enable innovation), Adoption (the active application of emerging technologies such as AI in production and services), and Adaptation (the capacity to modify technologies for local needs). The index ranges from 0 (lowest readiness) to 1 (highest readiness) and is sourced from the UNCTADStat Data Centre (UNCTAD 2024). Countries with higher FTRI scores are expected to leverage frontier technologies more effectively to accelerate economic growth and structural transformation.

5 Solow 1957; Hulten 2001.

6 Rodrik 2016.

7 UNCTAD 2021a.

8 ECA 2024a.

9 The Global Innovation Index (GII), published by the World Intellectual Property Organization, evaluates countries' innovation capacity and performance. High scores indicate robust institutional and structural support for turning ideas into products and processes, while low scores reflect weaker ecosystems. The 2025 edition benchmarks around 130 economies. The GII is calculated as the average of innovation inputs (capturing enabling conditions through five pillars: institutions, human capital and research, infrastructure, market sophistication, and business sophistication, and innovation outputs (assessing results through two pillars: knowledge and technology, and creative outputs. Although fewer in number, outputs carry a weight equal to inputs), measured across 81 indicators. Indicator values are normalized using the min–max method, converting raw data into a 0–100 scale, where higher scores denote stronger innovation outcomes.

10 WIPO 2024a; UNCTAD 2021b, 2024.

11 Kraemer-Mbula, Sheikheldin, and Karimanzira 2021.

12 WIPO estimates based on GII Database and data from Eurostat, OECD, RICYT, and UNESCO UIS (2023)

13 WIPO 2022.

14 WIPO 2023.

15 WIPO 2024b.

16 Kraemer-Mbula, Sheikheldin, and Karimanzira 2021.

17 Songwe 2020.

18 IMF 2004.

19 Dempere et al. 2023.

20 Maradana et al. 2017; Thi Thi et al. 2024.

21 Hasan and Tucci 2010; Gonzales 2023.

22 Mohamed et al. 2022.

23 Çetin 2013.

24 Shukla 2017.

25 Qamruzzaman and Jianguo 2017; Law et al. 2020.

26 Kasongo and Makamu 2024; Forson et al. 2021.

27 Anakpo and Oyenubi 2022.

28 Okumu et al. 2019; Jammeh 2022.

29 Otekunrin et al. 2021.

30 UNCTAD 2024.

31 IEA 2023.

32 Mothobi and Kebotsamang 2024; Kemgou Voptia and Stukalina 2025a, 2025b.

33 Kemgou Voptia and Stukalina 2025a, 2025b; Gao et al. 2024.

34 Ofori and Asongu 2021; Mhaka and Taonezvi 2024; Ofori et al. 2025.

35 Solomon and Van Klyton 2020; Kasongo and Makamu 2024; Anakpo and Oyenubi 2022.

36 Adejumo et al. 2020; Saba et al. 2024.

37 Wang and Chien 2007; Ahmed and Ridzuan 2013; Kurniawati 2022; Campos 2010; Aali Bujari and Venegas Martínez 2016; Hofman et al. 2016.

38 Das and Drine 2020; Filippi et al. 2023.

39 A summary of the methodology is provided in annex 2.1. For a full disposition of the methodology, please refer to the technical background paper available on request from the authors (an online link will be provided later,

40 The index ranges from 0 (lowest readiness) to 1 (highest readiness) (UNCTAD 2024). Countries with higher FTRI scores are expected to leverage frontier technologies more effectively to accelerate structural transformation and economic growth.

41 For more information on the methodology and data used, see the associated technical background paper. However, the variable definitions are provided in the annex 2.1. The dataset covers 47 countries over a 32-year period.

42 ECA calculations based on IMF, 2025a. World economic outlook database October 2025. Available at https://data.imf.org/en/Data-Explorer?datasetUrn=IMF.RES:WEO(9.0.0). Accessed on 09 December 2025.

43 Farole and Winkler 2014.

44 Rodrik 2016.

45 Alfaro et al. 2010.

46 Pritchett 2001; Hanushek and Woessmann 2012.

47 Acemoglu and Johnson 2007.

48 See a brief methodological note in the annex 2.1. For a more detailed analysis, see the background document [add URL].

49 ECA 2024b.

50 ECA 2023.

51 Ouedraogo and Kilolo 2024.

52 ECA 2023, 2024b.

53 ECA 2025.

54 Jordà and Taylor 2016; Alesina et al. 2023; Bomprezzi et al. 2022; Amedanou and Gomado 2025.

55 FTR Index captures five key components: ICT deployment (infrastructure availability and quality), skills (education and labour-market capabilities), R&D activity (publications and patents in 17 frontier technology areas), industry activity (high-tech manufacturing, ICT, and digital services), and access to finance (domestic credit to the private sector).

56 Eritrea, Liberia, Malawi, Nigeria, São Tomé and Príncipe, Seychelles, Somalia, and South Sudan are not included in the estimation sample due to missing observations in one or more of the key variables (capital, labour, or the frontier innovation readiness index).

57 Solow 1956.

58 World Bank 2024a.

59 Feenstra, Inklaar, and Timmer 2015.

60 ILO 2024. Parallel estimates with Solow residuals with the calibrated capital share parameter as a robustness check have also been conducted, and the results remain unchanged. Solow residuals using a capital income share calibrated at α=0.35 (implying a labour share of 0.65), a standard choice in cross-country growth accounting and widely used for African countries; see Collins & Bosworth (1996, 2003), Caselli (2005), and Ndulu & O'Connell (1999). This is also consistent with evidence that—once self-employment income is properly imputed—labour shares cluster around two-thirds across countries (Gollin 2002) (see also Penn World Table documentation).

61 UNCTAD 2024.

62 Archibugi and Coco 2005; Fagerberg et al. 2010.

63 Xie et al. 2024; UNCTAD 2021b.

64 World Bank 2024a.

65 UNDP 2024.

66 Ritchie, Rosado, and Samborska 2024.

67 Kaufmann, Kraay, and Mastruzzi 2010; World Bank 2024b.

CHAPTER 3 FRONTIER TECHNOLOGIES FOR AFRICA'S ECONOMIC TRANSFORMATION

The development and application of frontier technologies have the potential to accelerate the continent's economic transformation. No single definition of frontier technologies is globally agreed. They generally refer to cutting-edge, transformative, rapidly growing, and evolving technologies at the interface of major scientific breakthroughs and real-world applications.[1] These attributes distinguish them from other new or mature technologies. Given their broad scope, the chapter focuses on those emerging as strategic for structural transformation in Africa:

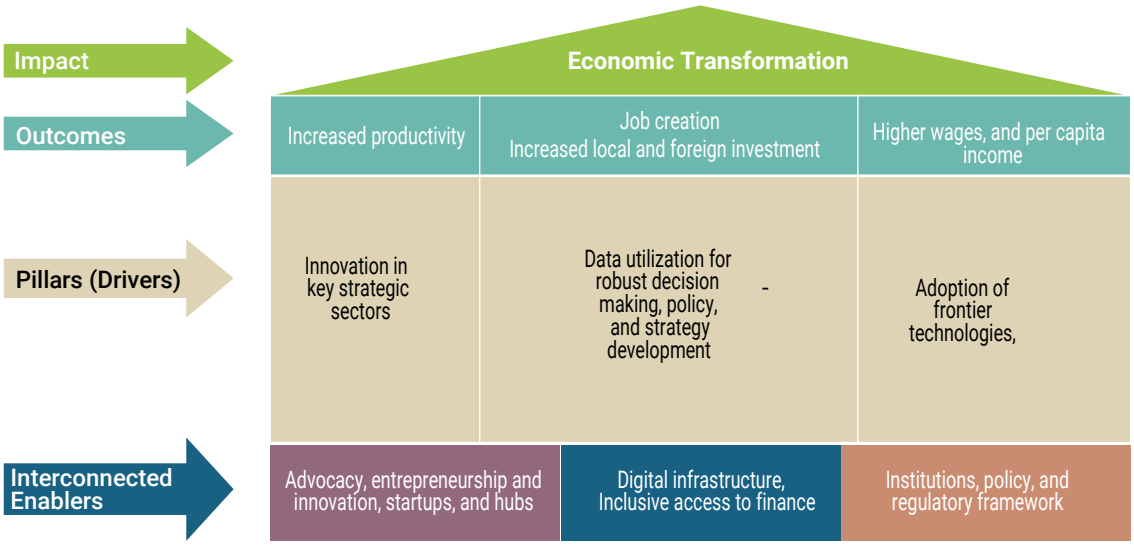
Digital technologies such as artificial intelligence (AI), the Internet of Things (IoT), blockchain, cloud computing, and supercomputing.

- Biological technologies such as gene editing, bioprinting, brain–computer interfaces, and synthetic biology.
- Physical technologies such as nanotechnology, advanced materials, 3D printing, robotics, autonomous vehicles, and other advanced hardware.
- Energy technologies such as solar energy generation and storage, hydrogen production and distribution, and wind and tidal power technologies.
- Advanced frontier technologies such as quantum science and nanotechnology.

Frontier technologies are interconnected, interdependent, and mutually reinforcing—advances in one area often accelerate progress in others.[2] For example, current investments in AI are driving the development of advanced materials and chips, data centres, and supporting infrastructure, which in turn drives progress in biotechnology, nanotechnology, materials science, and next-generation energy systems. Similarly, advances in biotechnology are also accelerating progress in other fields by generating large biological datasets for AI training, enabling new materials and sensors for robotics, and providing nanoscale design templates for self-assembling.

The African Union's Digital Transformation Strategy is the framework used here to analyse selected examples of frontier technologies applied in Africa (figure 3.1). The strategy promotes Africa's economic transformation through diversification, increased job opportunities, improved productivity, and resilience to achieve inclusive and sustainable growth across the continent.[3]

Figure 3.1 Analytical framework of the African Union's Digital Transformation Strategy



Source: ECA staff.

The framework identifies three principal drivers of Africa's economic transformation. First, innovation in key strategic sectors—such as agriculture, health, education, finance, energy, transportation, and manufacturing—is deemed a catalyst for increased productivity and improved service delivery.[4] Second, data use underpins evidence-based governance, informed policy and strategy development, business intelligence, and active citizen engagement across different sectors. Third, the widespread adoption of frontier technologies, including AI, blockchain, IoT, and robotics, accelerates operational efficiency, strengthens connectivity, and enhances system transparency and data transaction flow traceability.[5]

The framework also presents three interconnected enablers that support these drivers. First, well-developed digital ecosystems—including advanced digital infrastructure, inclusive access, research and development, and digital skills—are crucial for fostering sustainable innovation. Second, entrepreneurship and innovation startups, especially those in innovation hubs, translate data and frontier technologies into effective solutions tailored for local problems. Third, establishing a conducive policy and regulatory framework that encompasses data protection, technology standards, intellectual property rights, cybersecurity, and digital trade regulations lays the legal foundation necessary for advancing the innovation landscape.[6]

Box 3.1 Phases of technology diffusion

Technology adoption unfolds through a multiphase process, with each phase presenting distinct challenges and opportunities and requiring targeted interventions and specific actions:

Phase 1: Awareness and mobilization

This phase seeks to raise awareness of technological opportunities and risks, secure high-level political and institutional buy-in and support, and engage early adopters (research institutions, tech firms, wealthier individuals).

Phase 2: Strategy and infrastructure development

This phase focuses on developing national technology strategies and roadmaps; establishing legal, regulatory and governance frameworks; investing in foundational infrastructure and human capital; and creating innovation zones and centres of excellence.

Phase 3: Pilot implementation

This phase is characterized by several launches of pilot projects and practical cases. Governments may seek to provide support for startup ecosystems and early-stage investment. They may also promote inter-sectoral collaboration and launch capacity-building initiatives for public and private sector actors. The phase generally demands more resources than it contributes to the economy.

Phase 4: Scaling up and market consolidation

This phase focuses on scaling up successful pilot cases for wider uptake and integration in public and private sector production processes and service delivery. Efforts may include facilitating industrywide adoption and standard-setting, supporting new business models, facilitating mergers, partnerships, and acquisitions; and expanding access and reducing costs of use. Capacity building, skill development and innovative finance are also critical enablers throughout the technology diffusion process. The economic and social benefits of the technology become measurable at this stage.

Phase 5: Full societal integration

In this phase, the technology becomes embedded in public administration, economic activities, social systems, and the daily lives of citizens. Governments may promote continuous innovations that bring new applications and uses across all sectors and enhance technology governance within broader policy frameworks. Equally important is ensuring equity—so that all segments of society regardless of income, location, gender, or ability can benefit from technological advancements—and building resilience into systems through robust mechanisms to sustain technological solutions.

Source: Sahin 2006.

DIGITAL TECHNOLOGIES

The digital technologies most relevant to Africa's economy are identified based on their maturity, scalability, and alignment with pressing development needs. For instance, AI, IoT, blockchain, and energy technologies are essential for socioeconomic inclusion due to their cross-sectoral impact and foundational role in enabling broader digital transformation.

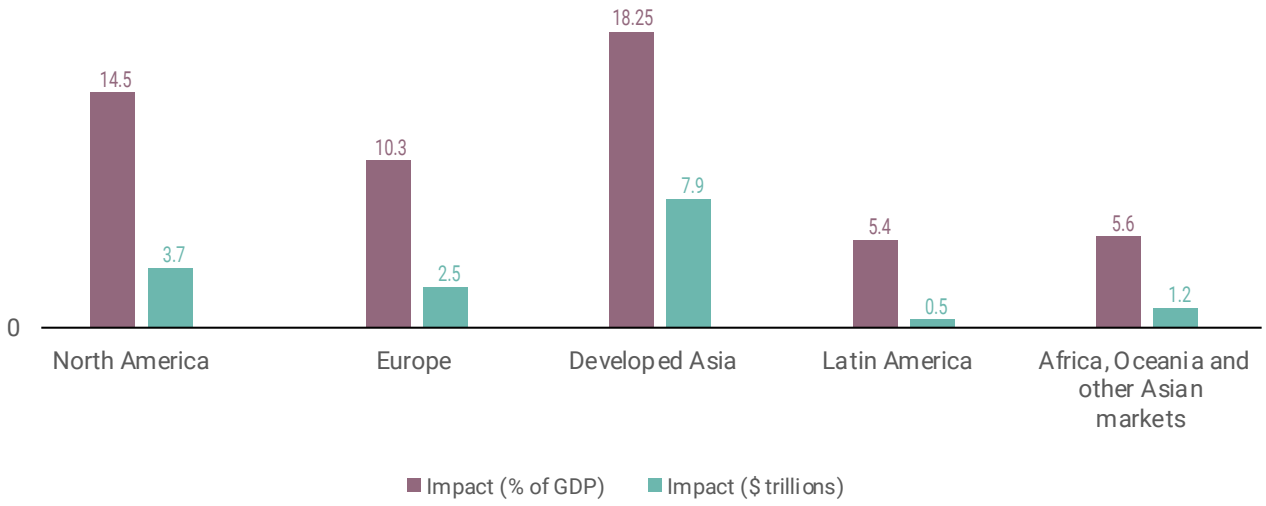
ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) presents opportunities to drive transformative change across multiple sectors, including healthcare, education, agriculture, finance, and public administration. To capitalize on these opportunities, the African Union (AU) developed the Continental Artificial Intelligence Strategy in 2024, with an Africa-centric, development-oriented, and inclusive approach to harness the benefits of AI in driving the continent's socioeconomic transformation.[7]

AI initiatives could boost the continent's economic growth by up to $1.2 trillion, contributing 5.6 per cent to the continent's GDP by 2030.

Generative AI (GenAI) is becoming essential for business operations, with 72 per cent of executives in South Africa, Nigeria, and Morocco ranking AI and GenAI as a top strategic priority for 2025. Since 2019, the number of AI startups in Africa increased by more than 70 per cent.[8] By 2024, there were more than 2,400 AI companies on the continent, with 40 per cent established after 2017 and the number of AI professionals rising by 40 per cent.[9] These initiatives could boost the continent's economic growth by up to $1.2 trillion, contributing 5.6 per cent to the continent's GDP by 2030.[10] But this projected contribution is lower than that of other regions across the globe due to much lower rates of adoption of AI technologies (figure 3.2).

Figure 3.2 Projected gains from AI adoption by 2030

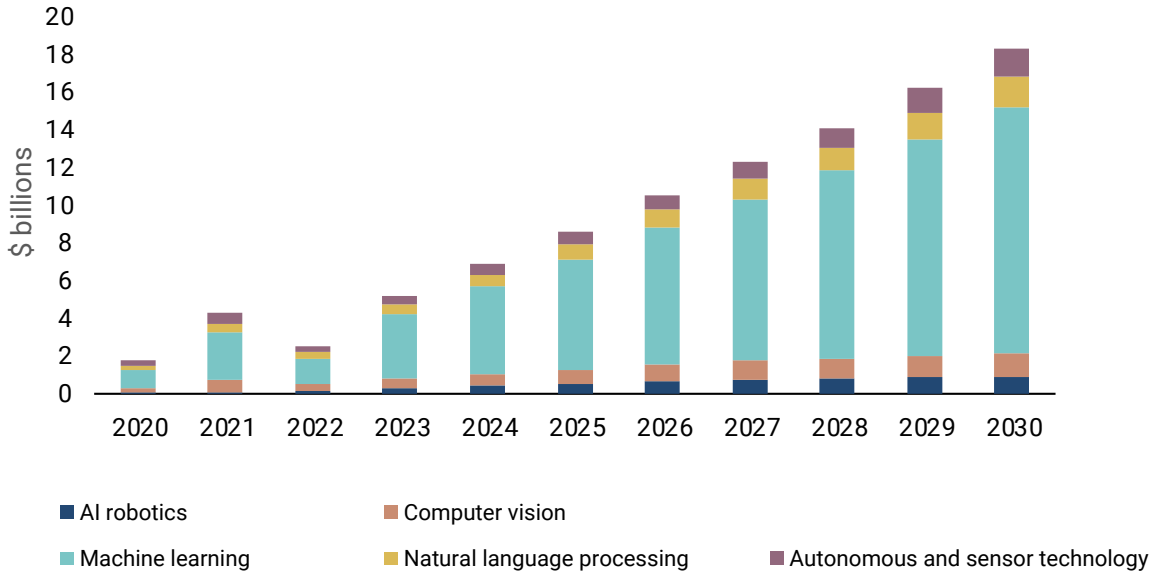


Source: PwC 2017.

Asia is the leading region, with a projected contribution of $7.9 trillion (18.3 per cent) to GDP, followed by North America with $3.7 trillion (14.5 per cent), and Europe with $2.5 trillion (10.3 per cent). North America and Asia are expected to have the largest economic gains, accounting for 70 per cent of the global economic impact from AI adoption by 2030.[11] Between 2020 and 2030, the market size of AI technologies is expected to grow rapidly (figure 3.3). These projections signal that Africa is most likely to see the biggest near-term opportunities for productivity and new businesses, particularly using machine learning to improve credit scoring and fraud detection in finance, optimize supply chains in agriculture, forecast demand in retail, and strengthen public services.

Between 2020 and 2030, the market size of AI technologies is expected to grow rapidly. These projections signal that Africa is most likely to see the biggest near-term opportunities for productivity and new businesses.

Figure 3.3 Market size of AI technologies in Africa, 2020–2030



Source: ITedge 2024.

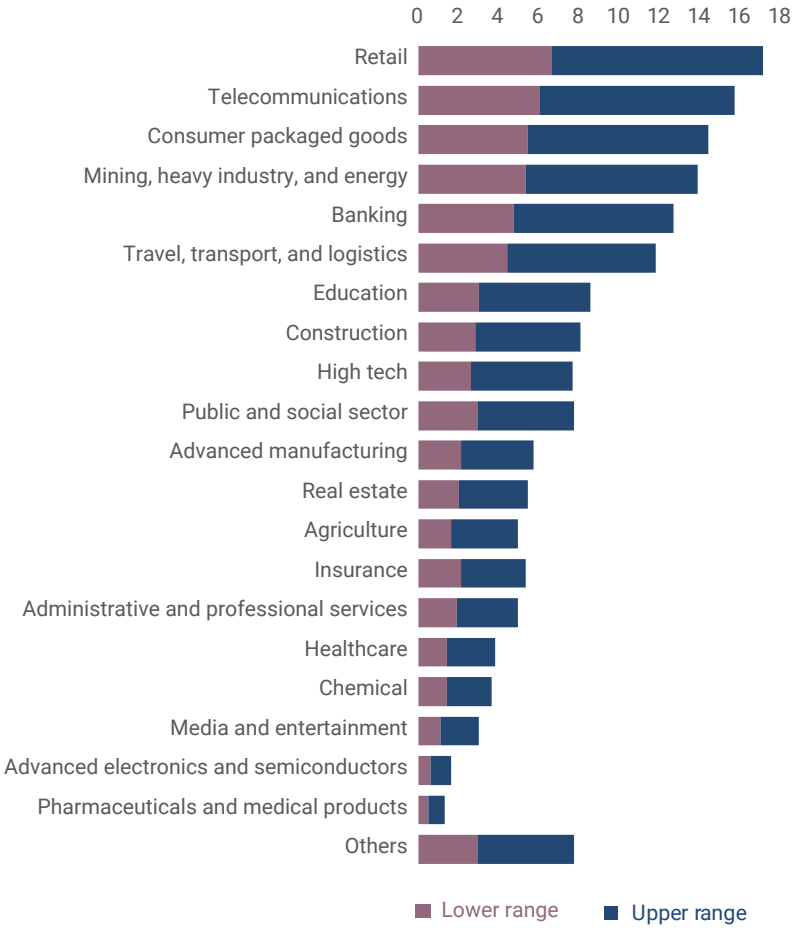
Natural language processing expands access through African languages in chatbots, translation, and voice services. There is a strong push for multilingual AI tools tailored to African languages, with more than 60 per cent of people preferring content in their native languages. Several companies are therefore developing smaller, efficient AI models and cloud infrastructure to support this trend, aiming for a "universal translator" for digital interaction. Among more than 2,000 languages spoken across Africa, only 42 (fewer than 2 per cent) are currently supported by some AI models, and fewer than 5 per cent have the datasets or toolkits that make them usable.[12]

To unlock the full potential of AI for Africa's development, policymakers should focus on expanding AI education and training, supporting the development of multilingual AI tools to increase digital inclusion, and establishing ethical AI regulations tailored to Africa's needs. These actions will help build local expertise, ensure accessibility for all language groups, and promote responsible innovation.

The sectors with the highest potential for productivity gains are retail trade, telecommunications, consumer packaged goods, mining and heavy industry, and banking and financial services (figure 3.4). They share three

traits: massive data flows, complex operations, and high costs from inefficiency or risk. AI in consumer goods can optimize demand forecasting, pricing, logistics, and customer engagement—and that in telecoms from automating network management and service delivery. Banking and financial services benefit from AI-driven risk assessment, fraud detection, and automation of back-office processes, where even small percentage improvements translate into substantial productivity and profit gains.

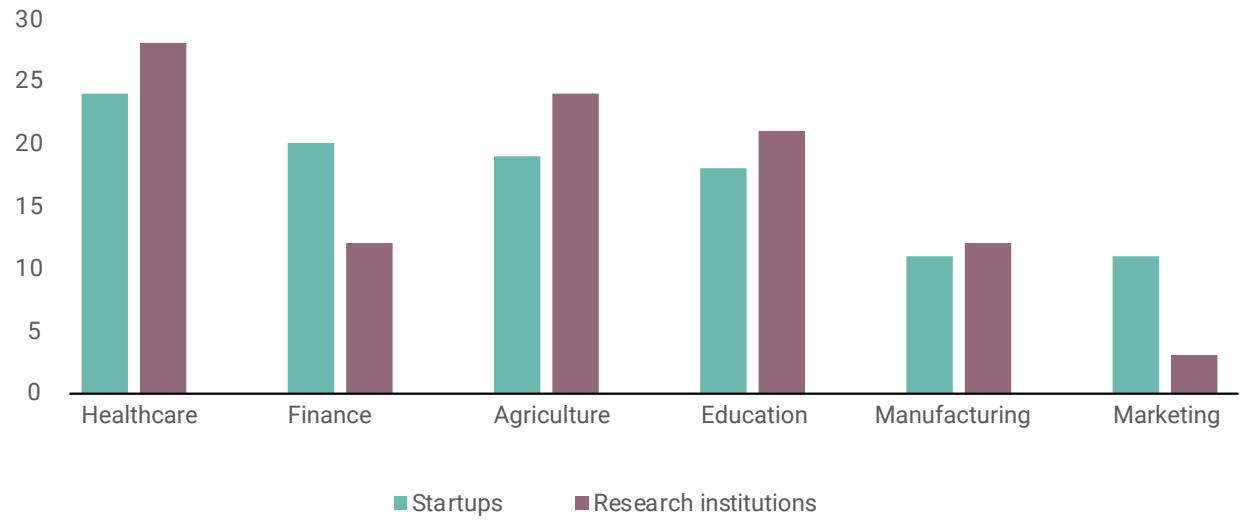
Figure 3.4 Productivity impact of AI in Africa by sector, through 2030



Source: McKinsey & Company 2025.

Healthcare has the highest share of AI startups in Africa, at 24 per cent, followed by finance (20 per cent), agriculture (19 per cent), education (18 per cent), and manufacturing and marketing (11 per cent) (figure 3.5). Healthcare also tops the list of AI research at 28 per cent, followed by agriculture (24 per cent), education (21 per cent), and finance and manufacturing (12 per cent).

Figure 3.5 AI startups and research in Africa, 2024



Source: Madu et al. 2024.

AI adoption and innovation are thus closely aligned with Africa's most pressing development needs. The concentration of AI startups and research in healthcare, finance, agriculture, and education shows that businesses and researchers are prioritizing sectors where AI can address gaps in access to medical services, financial inclusion, food security, and skill development, while also offering strong commercial potential. This pattern suggests that AI in Africa is not just technology-driven—it is problem-driven, with innovation focused on practical, high-impact use. It also indicates where future productivity gains and scalable solutions are most likely to emerge.

INTERNET OF THINGS

The internet of things (IoT) market on the continent, valued at $7 billion in 2024, is projected to reach $20 billion by 2031.[13] Several advances in IoT applications, including licensed cellular IoT connections and smartphone penetration, are contributing to the rapid growth of Africa's IoT market (table 3.1). From 2023 to 2030, the licensed cellular IoT connections in Sub-Saharan Africa are projected to double from 27 million to 51 million, and the number of internet users from 320 million to 527 million.[14] During the same period, the economic impact of mobile is projected to triple from $20 billion to $62 billion, and operators' revenue expected to grow from $38 billion to $61 billion.

Table 3.1 The status of IoT development indicators in Africa in 2024

	Africa	Arab States	Asia Pacific	Europe	CIS	Americas	World
Active mobile-broadband subscriptions (per 100 people)	51.5	85.2	96.8	112	108	125	94.6
Fixed-telephone subscriptions (per 100 people)	0.6	9.1	8.3	28.5	14.1	16.7	10.3
Mobile-cellular subscriptions (per 100 people)	97.5	104	112	125	147	114	112
Fixed-broadband subscriptions (per 100 people)	0.9	12.5	20.8	37.2	25.3	26.6	19.6
Population coverage - at least 2G (%)	93.8	97.4	98.9	99.8	99.1	96.9	97.9
Population coverage - at least 3G (%)	85.9	94.9	97.6	99.4	97.6	95.7	95.6
Population coverage - at least 4G (%)	70.9	86.9	96.2	99.3	94.3	93.7	91.8
Population coverage - at least 5G (%)	11	12.7	62.3	72.3	12	63.4	51.2

Source: ECA elaboration based on ITU (2024).

Africa's IoT market is growing, but it still lags other regions due to low broadband penetration. Challenges like power unreliability make it harder to deploy sensors, real-time monitoring, and large-scale device fleets. Many high-value IoT uses—precision agriculture, cold-chain logistics, remote patient monitoring, smart metering—either don't scale, become too costly to operate, or remain confined to pilot projects. To close the gap, governments and regulators need to prioritize expanding affordable broadband—fibre backbones and 4G/5G where viable, plus community networks and satellite. They can also target incentive grants, tax relief, procurement programs, and regulatory sandboxes to help IoT startups move from pilots to deployment. And they can strengthen regional collaboration for spectrum management.

BLOCKCHAIN

Blockchain technology is being applied to a range of practical uses, providing access to capital for startups, supporting energy infrastructure, and improving market price transparency. In various sectors around the world, it is improving transparency, efficiency, and security. PwC estimated that blockchain could contribute up to $1.76 trillion to the global economy.[15]

In 2024, blockchain venture funding represented 7.4 per cent of all-sector venture funding in Africa and accounted for 12.7 per cent of the total deals. Globally, blockchain businesses raised $12.1 billion in 1,309 deals, a 14 per cent increase in funding and a 6 per cent increase in the number of deals over 2023.[16] The majority of global blockchain venture activities were concentrated in North America, with 50 per cent of the funding and 40 per cent of the deals.

S

Figure 3.6 Blockchain funding and deals, 2024

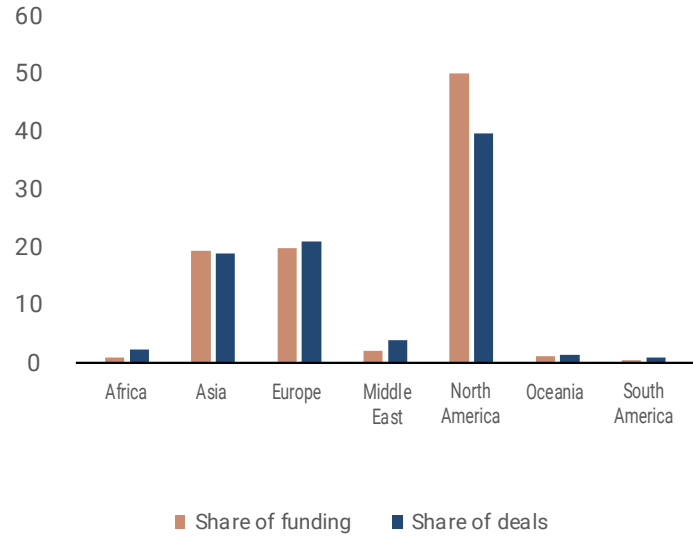
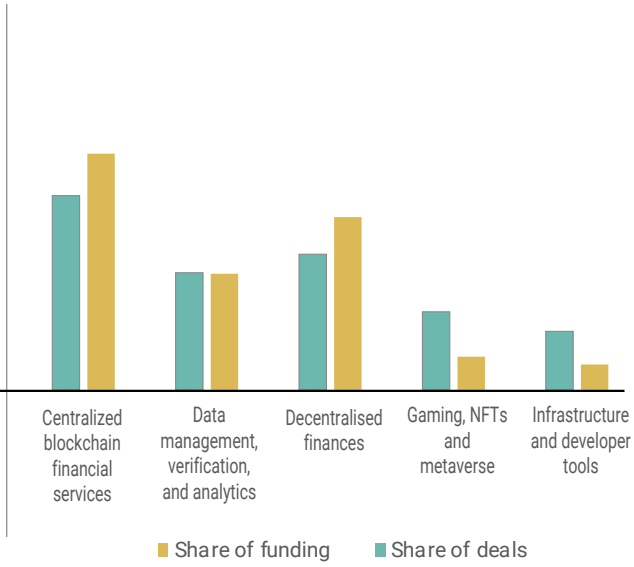


Figure 3.7 Blockchain funding and deals by industry, 2024



Source: Coetzee and Stoffberg 2024.

African blockchain ventures raised $122.5 million across 30 deals in 2024, a 36 per cent decline in capital raised in 2023, as the number of deals increased by 15 per cent. Africa's share of annual global blockchain venture deals increased from 2.1 per cent in 2023 to 2.3 in 2024, as its share of venture funding fell from 1.8 per cent to 1.0 per cent.[17] Increasing deals and declining funding suggests significant value opportunities in the early-stage African blockchain ecosystem. Investors in Africa's blockchain industries are showing increasing preference for solutions that integrate with regulated financial system services for cross-border use, and infrastructure for data verification and compliance.[18]

Blockchain is facilitating crypto payments, remittances, and trade opportunities for small and medium enterprises (SMEs). And it has the potential to significantly improve international trade finance.[19] In industries where traceability is crucial, as in agriculture, mining, and food exports, blockchain enables producers and consumers to verify the origins of goods. With mobile money already well established, thanks to platforms like M-Pesa and MTN Mobile Money, blockchain is now streamlining cross-border payments and remittances. BitPesa and Yellow Card are reducing the costs and delays typically associated with international transfers. And Nigeria, Kenya, and South Africa rank among the top users of cryptocurrencies, often turning to digital assets as a safeguard against inflation and currency instability.[20] In Ghana, pilot programs are exploring blockchain to enhance the transparency of land transactions, aiming to eliminate issues of double-selling and fraudulent ownership claims.

The Trade Logistics Information Pipeline, which already supports real-time data sharing between Kenya and the European Union (EU) across the flower value chain, is expanding to pilot projects under the Kenya–UK Trade Data Corridor and the pharmaceuticals trade between Kenya and India.[21] Its findings are baselining the country's digital trade ecosystem, outlining opportunities, gaps, and challenges, and identifying priority areas of action to use blockchain for trade facilitation and recommend a strategic and operational roadmap.

Africa's share of annual global blockchain venture deals increased from 2.1 per cent in 2023 to 2.3 in 2024, as its share of venture funding fell from 1.8 per cent to 1.0 per cent.

These initiatives demonstrate that blockchain is evolving beyond cryptocurrencies to drive digital transformation in Africa's financial services, agriculture, transport, energy, and food security. But the rapid expansion faces regulatory uncertainty, cryptocurrency volatility, illicit activity risks, inadequate data protection, and a shortage of skilled professionals. Realizing blockchain's potential depends on robust infrastructure, harmonized regulations, reliable data, and supportive policies that foster collaboration among governments, businesses, and communities.

These initiatives demonstrate that blockchain is evolving beyond cryptocurrencies to drive digital transformation in Africa's financial services, agriculture, transport, energy, and food security.

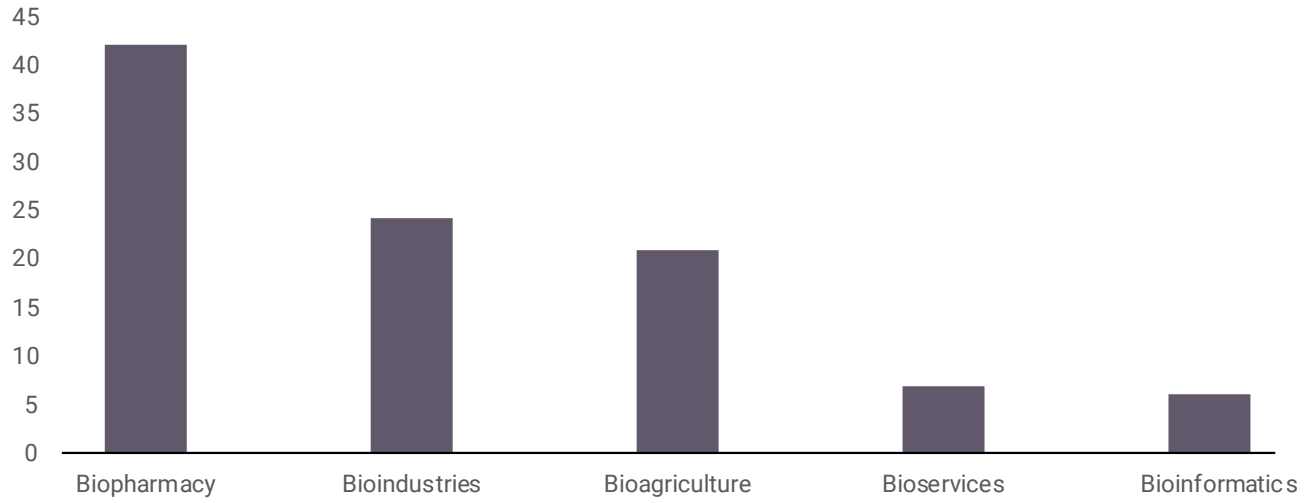
BIOLOGICAL TECHNOLOGIES

Biological technologies cover advances and the development and application of technologies derived from living systems, particularly in healthcare, agriculture, and industry. The sector is rapidly expanding worldwide and in Africa, driven by genetic sequencing, personalised medicine, and new treatments for chronic and rare diseases.

BIOLOGICS FOR HEALTHCARE

The global market for biotechnology, estimated at about $1.6 trillion in 2023, is expected to reach $3.9 trillion by 2030, driven largely by genetic sequencing, personalized medicine, and demand for treatments of chronic and orphan diseases.[22] Although data on Africa are limited, estimates suggest that the African biotechnology sector, valued at $73.4 billion in 2022, was projected to reach $138.2 billion by 2030, at an annual rate of 8.2 per cent.[23] Demand for biologics, expected to account for about half the market, will continue to drive growth, followed by agricultural and industrial biotechnologies. In 2023, the African biotech sector attracted investment of more than $500 million, with numerous startups scaling operations to meet national and international demand.[24] Biopharmacy accounts for about 42 per cent of the market, followed by bioindustry at 24 per cent, bioagriculture at 21 per cent, bioservices at 7 per cent, and bioinformatics at 6 per cent (figure 3.8).[25]

Figure 3.8 Global biotechnology market shares by application, 2024



Source: Precedence Research 2025.

Recent developments in the biopharmaceutical industry, such as gene sequencing technologies, particularly the next-generation sequencing (NGS) technologies, improve healthcare. For example, new gene sequencing technologies have reduced the time and cost to completely decode the human genome from about $2.7 billion and a decade in 2001 to about $500–600 in a few hours by 2023.[26] The Middle East and Africa Genome Sequencing Market is projected to grow from $8.9 billion in 2025 to $ 23.4 billion by 2031, at 17 per cent a year—if demand for advanced NGS and clinical applications continue to expand.[27] Since the Covid-19 pandemic, the number of African countries with functional NGS capacity in public health laboratories grew from 7 in 2019 to 31 in 2022.[28] And by 2024, more than 50 per cent of African countries were equipped with an in-country sequencing capacity.[29]

During the Covid-19 pandemic, African public health institutions rapidly expanded genomic sequencing capacity, shifting the continent from being largely dependent on external laboratories to generating substantial genomic data locally. Before the pandemic, only 7 of Africa's 55 AU Member States had in-country NGS capability; by 2022, 31 countries had established such capacity. Africa CDC reports that genome sequencing efforts tracked more than 120,000 SARS-CoV-2 genomes from 53 countries, compared with fewer than 5,000 sequences early in 2020, reflecting a major uplift in surveillance infrastructure.[30]

The Kenya Medical Research Institute (KEMRI) in Kilifi is a leading example of this transformation. Before Covid-19, its genomic lab produced around 300 sequences annually for research. With pandemic demand, the lab scaled up to sequence more than 8,000 SARS-CoV-2 genomes and increased weekly capacity from roughly 24 sequences to nearly 700. This enabled real-time surveillance of variants and contributed genetic data supporting public health responses in Kenya and neighbouring countries.[31]

In South Africa, the Network for Genomic Surveillance quickly became a continental leader in genomic research. Its genomic network sequenced and shared more than 44,700 SARS-CoV-2 genomes, helping to identify and monitor key variants such as Beta and Omicron. These data informed national public health measures, vaccine strategy adjustments, and contributed to global databases used by researchers worldwide.[32]

Although data on Africa are limited, estimates suggest that the African biotechnology sector, valued at $73.4 billion in 2022, was projected to reach $138.2 billion by 2030, at an annual rate of 8.2 per cent.

African startups are now adding economic and scientific value beyond public health surveillance by building foundational genomic and diagnostic capabilities. 54gene, a Nigerian genomics research company, aimed to build one of Africa's largest biobanks. Through early funding, including more than $15 million in Series A funding led by Adjuvant Capital, it invested in genomic data collection and lab capabilities to support research focused on African genetic diversity, noncommunicable conditions, and infectious disease genomics.[33] Although the company's operational trajectory has evolved over time, its initial growth demonstrated investor confidence in African genomic science and catalysed local sequencing capacity, including testing infrastructure during Covid-19 while training researchers and building local expertise.

Africa's biotechnology thus has strong growth potential but faces challenges. Investing in genome sequencing labs and training is key to improving disease surveillance, personalised medicine, and health emergency preparedness. Supporting biotech startups with funding and regulatory reform will drive innovation and commercialization. Promoting regional collaboration in bioagriculture by harmonizing standards and supporting joint research will accelerate biotech adoption and boost food security. These actions will help Africa reap biotech benefits in healthcare, agriculture, and industry, and strengthen its global position.

PHYSICAL TECHNOLOGIES

Transportation accounts for about 20 per cent of greenhouse gas emissions, with road transportation contributing three-quarters of this share.[34] The transport sector in Africa relies heavily on roads, which accounts for roughly 80 per cent of the modal share. So, the transformation of road vehicles is essential to achieving zero-carbon targets. E-mobility presents an opportunity for technology "leapfrogging" in Africa, offering improvements in transport accessibility as well as enhancements to both climate and public health outcomes.[35]

Africa's endowment with critical minerals for batteries, such as cobalt, manganese, and lithium, provides opportunities for the continent to participate in the EV value chain. Globally, 3.5 million more electric vehicles were sold in 2023 than in 2022, a 35 per cent increase in sales. These trends indicate strong growth in electric car markets.[36] While the EV market in Africa is still in its infancy, it is experiencing rapid growth due to government support and incentives. Electric car sales on the continent more than doubled to reach nearly 11,000 in 2024.[37] The EV market in Africa is projected to grow annually at 10.6 per cent, resulting in a projected market volume of $314 million by 2029.[38]

EVs benefit health and the environment by reducing CO_2 emissions and provide substantial economic benefits by generating employment, enhancing energy infrastructure, reducing fuel imports, and lowering the cost of fuelling vehicles. Siemens research showed that "each EV life will result in roughly $12,000 in fuel savings, $3,500 in ratepayer benefits, and $7,000 in economic growth."[39]

Africa's readiness for EVs varies, with few countries well-positioned for adoption and many others lagging. According to the EV Readiness and Impact Index, 12 African countries show high readiness for EV adoption with enabling policies and infrastructure.

- Emulators like Seychelles, Morocco, Mauritius, and South Africa have market conditions similar to those of developed countries but face financing challenges.

Africa's endowment with critical minerals for batteries, such as cobalt, manganese, and lithium, provides opportunities for the continent to participate in the EV value chain.

- Innovators like Kenya and Rwanda focus on two- and three-wheeler EVs, supported by strong fintech sectors.
- Stragglers face multiple challenges, with only 28 per cent having national EV targets and 76 per cent with low motorisation rates.

In early 2025, fewer than 1,000 electric vehicle charging stations were operational across 26 African countries, serving an expanding fleet of more than 400,000 electric vehicles.[40] South Africa (~400), Egypt (300), Kenya (235), Morocco (120), Tunisia (140), and Ethiopia (100) have the highest number of charging stations on the continent. Countries in other world regions perform better than African countries in developing EV infrastructure. In 2023, China accounted for 70 per cent of the global public charging infrastructure for light-duty vehicles (LDVs). By the end of 2023, Europe would have exceeded 600,000 public EV charging points. The number of public LDV chargers in Europe is expected to increase to about 2.7 million by 2035. As of 2024, there were more than 192,000 publicly accessible charging ports in the United States, with roughly 1,000 new public chargers installed weekly.

Eighteen of 26 countries in an ECA survey were developing EV strategies and enacting supportive policies, indicating growing recognition of EVs promoting sustainable transportation. Policies and initiatives governing electric vehicles encompass a range of measures, including tax incentives, reduced import duties, charging infrastructure, and support for local manufacturing. But policy maturity remains uneven. Some countries have enforceable legal mandates (South Africa, Nigeria, Ethiopia), while others rely on aspirational roadmaps or pilot programs.[41]

Ethiopia leads in prioritizing EVs in Africa. In 2024, Ethiopia banned the import of nonelectric private vehicles (combustion-powered); the first country in the world to do so. Its automotive industry has several firms producing various types of EVs (table 3.2). But the underuse of production capacity is significant, with many firms operating at less than 50 per cent of their capacity due to low demand for specific products or to potential operational inefficiencies. The production of minibuses and light vehicles is stronger relative to the production capacity, but that of buses, three-wheelers, and light trucks is weak. So, it is important to understand market demand, resolve operational bottlenecks, and strengthen marketing initiatives.

Table 3.2 Ethiopia's EV production and capacity, 2023/24

Types of product	Capacity per year	Production
Automobiles	1,350	85
Three-wheelers	700	78
Minibus	350	112
Bus	100	20
Four-wheel minicar	100	36

Source: Ethiopia Ministry of Transport and Logistics and Ministry of Industry.

ENERGY TECHNOLOGIES

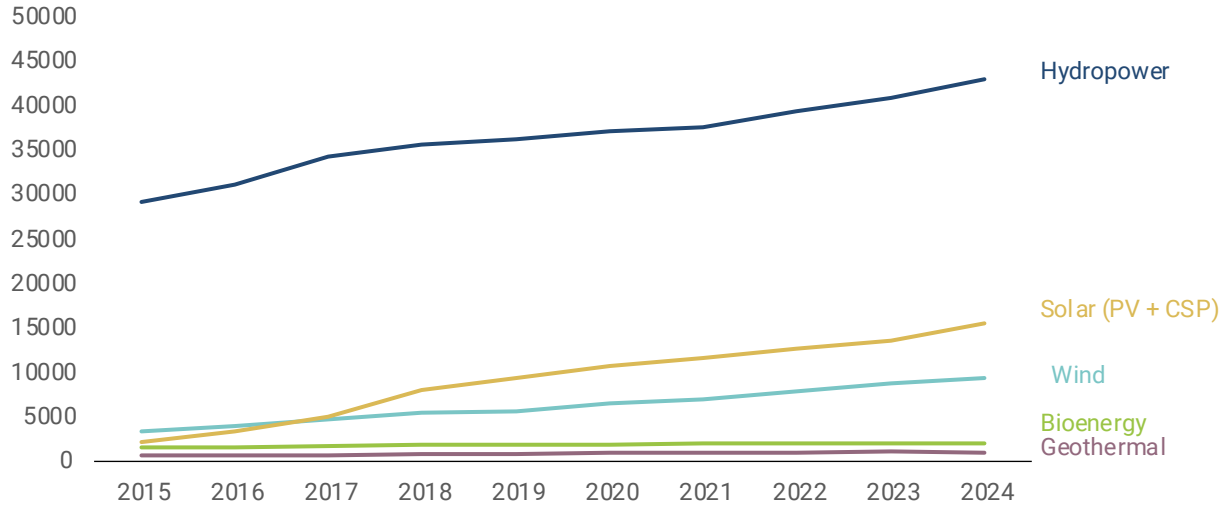
Africa has immense renewable energy endowments—60 per cent of global solar energy potential,[42] 1 per cent of its wind resource potential,[43] 20 per cent of its geothermal energy potential,[44] and great hydro power potential. Despite the vast renewable energy potential and registered progress in developing them, challenges persist to scaled deployment.

To meet the 2030 target of 300 GW, renewable energy generation must increase from 8 GW to more than 32 GW annually. This target may be modest in view of the data centres that support the use of AI. Renewables are expected to account for 45 per cent of Africa's energy capacity by 2035, reshaping the continent's energy sector.[45]

In Africa, more than 23 GW of new solar capacity projected to be installed by 2028—more than doubling current levels (figure 3.9).[46] Declining cost is the main driver behind this surge, along with the growth of the local solar industry. South Africa, Egypt, and Morocco lead in solar energy generation capacity increase, but 18 countries were expected to install at least 100 MW of new solar capacity in 2025. Off-grid and mini-grid solar solutions electrify rural areas, with the goal of powering two-thirds of mini-grid systems by 2040.[47]

Africa has immense renewable energy endowments—60 per cent of global solar energy potential, 1 per cent of its wind resource potential, 20 per cent of its geothermal energy potential.

Figure 3.9 Installed renewable energy capacity in Africa, 2024



Source: ECA analysis based on IRENA (2025).

Off-grid solar aims to power two-thirds of mini-grid systems by 2040, crucial for rural electrification. Wind power is expanding regionally, with onshore capacity rising from 1 GW in 2015 to nearly 20 GW in 2025, led by South Africa, Morocco and Egypt.[48] Starting a project requires a significant investment, but has lower lifecycle costs. A typical wind turbine costs between $2.6 million and $4 million per MW;[49] Kenya's Lake Turkana farm, with 365 turbines, cost approximately $700 million, facing funding and delay challenges, with 16 partners involved.[50]

Overall, the cost of renewable energy technologies by capacity has declined significantly. However, capital requirements to expand generation to meet growing energy needs are sizeable. The 2024 assessment by IRENA on renewable energy installed costs indicate that solar PV requires $691/kW capacity, concentrated solar power about $3,677/kW, onshore wind estimated at $1,041/kW and offshore wind at $2,852/kW.[51] Significant expansion of generation capacity would therefore require capital outlays.

Africa faces limited access and higher cost to global capital. This imbalance is maximum in Africa which accounts for only 2 per cent of global clean energy investments, despite possessing disproportionate clean energy resource endowments.[52] The borrowing costs for developing countries reach rates four times higher than the United States; with average borrowing cost of the United States at 2.8 per cent, Asia and Oceania at 5.5 per cent, Latin America and the Caribbean at 7.1 per cent, and Africa at 9.8 per cent.[53] So, while declining costs of renewable energy technologies provide opportunity, access and cost of capital impede the rate of progress in Africa. Reform of the global financial architecture and better access to affordable capital remain crucial to accelerate progress in Africa.

Energy storage is crucial for expanding Africa's renewable energy capacity, mitigating intermittency, facilitating demand response, and improving grid dispatchability. Relying solely on traditional grids will not guarantee universal electricity access, with projections indicating that 600 million people may still lack power and 150 million could face unreliability by 2025. Off-grid battery solutions are essential.[54] Over the past 20 years, the growth of renewable energy storage has improved electricity access, as manufacturers increase production. A 2024 survey shows Africa's storage capacity at 18 GWh, with future adoption of advanced batteries in solar and other renewable sources. In 2025, South Africa was expected to lead a new 2,052 MWh project from its Battery Energy Storage programme supplementing its assets.[55]

Green hydrogen has the potential to revolutionize renewable energy, with Africa aiming to take a

leading role. South Africa, leveraging its existing infrastructure, is focusing on green hydrogen in mining and manufacturing and has launched the Hydrogen Society Roadmap for collaboration. Namibia plans extensive renewable projects to export green hydrogen to Europe. Kenya aims to achieve 100 per cent renewable energy by 2030, replacing diesel in heavy transport with green hydrogen. Nigeria is diversifying its energy sources by using northern renewable energy and including hydrogen in its Energy Transition Plan. Egypt is expanding its investments in green hydrogen, using renewable energy from the Red Sea and Sinai, and collaborating with Siemens to boost its export capacity. Morocco is integrating green hydrogen into projects such as the Noor Ouarzazate Solar Complex. Mauritania's AMAN project has attracted $40 billion for 30 GW of wind and solar energy. And Algeria, Angola, Democratic Republic of the Congo, Ethiopia, and Tunisia are developing or have established national hydrogen strategies.[56]

Green hydrogen can diversify Africa's industrial base by providing clean fuel for sectors that are difficult to electrify, such as heavy industry, shipping, and fertiliser production, thereby promoting sustainable economic growth. It offers a solution to Africa's energy deficit by harnessing abundant renewables to produce clean fuel domestically, speeding up electrification and lifting millions out of energy poverty. Although challenges remain, including high upfront costs and infrastructure needs, coordinated government policies, international partnerships, and stable long-term contracts are driving swift progress. Africa's green hydrogen revolution is not just an energy transition—it is a transformative opportunity to lead globally in clean energy innovation, economic resilience, and climate action.

ADVANCED FRONTIER TECHNOLOGIES

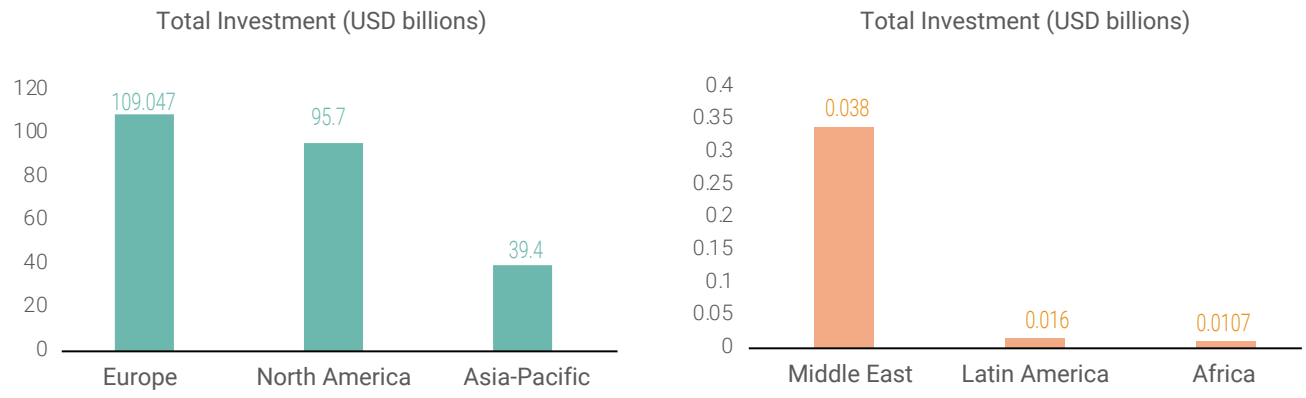
QUANTUM SCIENCE

In 2024, Egypt, Ghana, Senegal, and South Africa proposed a resolution on quantum science at the United Nations, showing Africa's determination to shape the future of quantum science.[57] The resolution (A/RES/78/287) was adopted by consensus by the General Assembly in June that year, with the purpose of building capacity and raising public awareness throughout the global scientific community.[58] Africa's ambition has been translated into grassroots efforts to nurture talent and build research networks and attract investment, mainly through global partnerships. In 2025, scientists from China and South Africa (Stellenbosch University) successfully established the world's longest intercontinental quantum satellite link, spanning 12,900 km.[59] The initiative aims to enhance secure global communications with quantum encryption, promote international scientific collaboration, showcase quantum technology's transformative potential for data transmission, and lay the foundation for future quantum communication networks that drive innovation and economic growth.

In 2024, Egypt, Ghana, Senegal, and South Africa proposed a resolution on quantum science at the United Nations, showing Africa's determination to shape the future of quantum science.

But Africa hosted only 0.0043 per cent of global investment in quantum computing in 2025, as Europe led with 45 per cent of the global investment value, followed by North America with 39 per cent and Asia Pacific with 16 per cent (figure 3.10). This disparity underscores the urgent need for Africa to accelerate its quantum technology development and participation on the global stage. While normative leadership and pilot initiatives—such as satellite-based quantum links—signal growing participation, the continent's quantum technology field currently encounters limited investment and an insufficient pool of skilled professionals, which restrict research infrastructure, hinder talent retention, and impede workforce development.

Figure 3.10 Total investment in quantum computing, 2025



Source: ECA staff based on data from Qureca Spain (2025).

To overcome these barriers and fully realize Africa's potential in quantum science, it is essential to establish dedicated quantum research hubs, strengthen international collaborations with leading institutions, and implement robust training programs to build a skilled workforce. Strategic emphasis should be placed on high-impact applications such as secure communications and advanced materials science. Furthermore, policy support and effective regional coordination are critical to translating these goals into measurable progress, fostering economic growth, and positioning Africa as a global leader in quantum technologies.

NANOTECHNOLOGY

The Middle East and Africa nanomedicine market, valued at $16.2 billion in 2024, is projected to reach $48.2 billion by 2033, at an annual rate of 12.9 per cent.[60] The global nanotechnology market, valued at $118.7 billion in 2026 and is projected to reach $220.8 billion by 2031 with 13.2 per cent annual growth.[61] Medical and healthcare sectors led the nanotechnology market, accounting for a 26.4 per cent share of the market size in 2025. Energy storage is expected to grow at 15.6 per cent a year through 2031. Pharmaceuticals led the market share with a 36.0 per cent share in 2025, while semiconductors are expected to show the quickest expansion by 2031 at nearly 18.5 per cent a year (table 3.3).

Table 3.3 Top market share holders and fastest-growing nanotechnology industries in the world

	Top market share holders in 2025	Market share in 2025 (%)	Fastest growing between 2026 and 2031	Compound annual growth rate by 2031 (%)
Manufacturing	Bottom-up	59.9	Top-down	15.1
By type	Nanomaterials	36.8	Nanodevices	16.7
By application	Medical and healthcare	26.4	Energy storage	15.6
By end user	Pharmaceuticals	36.1	Semiconductors and display original equipment manufacturers	18.5
By geography	Asia-Pacific	38.5	Middle East and Africa	13.8

Sourcee: ECA staff based on data from Mordor Intelligence (2025).

Nanotechnology is being used in many industries, but some sectors are leading the way and growing faster than others.

Nanotechnology is being used in many industries, but some sectors are leading the way and growing faster than others.

1. Manufacturing methods: In 2025, the "bottom-up" approach dominated manufacturing with 60.6 per cent of the market. However, "top-down" methods are growing faster, with an expected annual growth rate of 15.1 per cent by 2031. This means that new ways of making nanomaterials are gaining ground and could become more important in the future.
2. Type of nanotechnology: Most of the market in 2025 was focused on nanomaterials (36.8 per cent), but nanodevices are expected to grow quickly, with a yearly growth rate of 16.7 per cent. This suggests that devices made using nanotechnology, such as sensors or chips, will become more widespread.
3. Applications: The biggest area for nanotechnology in 2025 was medical and healthcare (26.4 per cent). Energy storage (such as better batteries) was the fastest-growing application, with a growth rate of 15.6 per cent a year.
4. End users: Pharmaceuticals are the largest users of nanotechnology (36.1 per cent), but the fastest-growing group is electronics manufacturers, especially those making semiconductors and display screens, at 18.5 per cent annual growth.
5. Geography: The Asia-Pacific region holds the largest share of the nanotechnology market (38.5 per cent), but the Middle East and Africa are experiencing rapid growth, with a 13.8 per cent annual increase.

Egypt launched its Nanotechnology Centre in 2008 with support from multiple ministries and international partners.[62] The centre includes more than two dozen specialized laboratories and focuses on a mix of applications, including healthcare, biosensors, and advanced materials, making it one of the most comprehensive nanoscience facilities in North Africa. Its mission is to generate intellectual property, strengthen applied research infrastructure, and support economic competitiveness through nanotechnology applications. Academic research in Egypt further complements national efforts. For example, cancer nanotechnology research units at major universities are exploring nanoformulations to improve targeted chemotherapy and enhance drug delivery to tumour tissues, with outcomes documented in peer-reviewed literature as examples of pharmaceutical nanotechnology promising more effective and less toxic treatments.

In Nigeria, nascent nanotechnology research groups at institutions such as the University of Nigeria and University of Lagos are building capacity in nanoscience and materials research. Nigerian researchers have contributed to growing publication output in nanotechnology increasing from a handful of articles in 2010 to dozens per year by 2020, though overall output remains lower than in South Africa and Egypt. This trend reflects both growing interest and persistent challenges such as limited access to advanced instrumentation, funding constraints, and the absence of comprehensive national nanotechnology policies.[63] Emerging research in Nigerian universities also touches on nanotechnology applications for environmental and biomedical problems. Nigerian teams are exploring nanomaterials with antimicrobial properties and potential uses in diagnostics and treatment development, particularly for infectious diseases that disproportionately affect African populations.[64]

In South Africa, the Council for Scientific and Industrial Research (CSIR) hosts the National Centre for Nano-Structured Materials, established in 2007 as part of the government's nanotechnology strategy. The centre conducts advanced research on nanomaterials for sensors, water remediation, and biomedical applications, and supports the development of skills and infrastructure for nanotechnology R&D in the country. It also facilitates broader access to high-tech equipment for universities and industry partners, helping to build human capital and research output in applied nanoscience. Researchers at CSIR and in affiliated institutions are exploring nano-enabled drug delivery systems for infectious diseases, including tuberculosis, by encapsulating therapeutic agents to improve targeting, reduce side effects, and enhance bioavailability, an approach highlighted in South Africa's nanotechnology research strategy and planning documents.[65]

With Africa rich in materials, nanotechnology and advanced materials, science could offer opportunities

for value addition to natural resources, participation in the production of high-tech products (such as wafers and semiconductors). Strategic investment in nanomedicine, renewable energy storage, and robust partnerships with universities and global laboratories will enable the continent to address region-specific health challenges, add value to natural resources, foster high-tech manufacturing, and create new employment opportunities. These steps are essential for accelerating Africa's participation in the global innovation ecosystem and improving public health and economic resilience.

The trends in advanced frontier technologies across Africa reveal a landscape of rapid growth, innovation, and significant economic potential. From AI and the IoT to blockchain, quantum technology, biotechnology, and nanotechnology, African countries are embracing cutting-edge advances to address local challenges and drive sustainable development.

The trends in advanced frontier technologies across Africa reveal a landscape of rapid growth, innovation, and significant economic potential. From AI and the IoT to blockchain, quantum technology, biotechnology, and nanotechnology, African countries are embracing cutting-edge advances to address local challenges and drive sustainable development. Despite Africa's comparatively low share of global investment in various technologies, the continent's youthful population, growing talent base, and expanding innovation ecosystems position it to capture greater economic value in the coming years. The ongoing efforts to scale renewable energy, build research networks, and develop strategic policies will be crucial for translating technological momentum into inclusive growth, job creation, and enhanced competitiveness on the global stage.

A group of people use their smartphones, technology and social networks in Africa.© Adobe Stock

TRANSFORMATIVE POTENTIAL OF FRONTIER TECHNOLOGIES ACROSS SECTORS

AGRICULTURE

Agriculture, the economic and societal anchor of most African economies, employs a substantial portion of the population.[66] But it is plagued by low productivity and vulnerability to climate change. Offering a clear pathway to transformation are such frontier technologies as precision agriculture, smart farming, blockchain tracing, and AI. These tools enable data-driven interventions to optimize farming practices, enhance productivity, and build resilience. Early pilots in East Africa have already demonstrated yield increases of 10–20 per cent with the use of digital tools.[67] For a continent where more than 90 per cent of agriculture is rainfed, technologies like AI-assisted climate warning systems, as in Rwanda, improve outcomes by helping farmers adjust to climate variability. Botswana's Lobu Small Stock Farm project shows how smart agriculture can enhance productivity and economic resilience in the livestock sector (box 3.2)

Offering a clear pathway to transformation are such frontier technologies as precision agriculture, smart farming, blockchain tracing, and AI. These tools enable data-driven interventions to optimize farming practices, enhance productivity, and build resilience.

Box 3.2 Smart agriculture in Botswana

Botswana's Lobu Small Stock Farm was established in 1978 to support farmers in the Kgalagadi District with top breeds of Karakul sheep. The government took measures to resuscitate the farm and transform it into a centre of excellence by establishing strategic partnerships and implementing smart agriculture technologies and modern infrastructure. The initiative's primary goal is to improve sustainability, competitiveness, and resilience in small stocks, in line with Botswana's Vision 2036 and the push towards a Fourth Industrial Revolution.

The UN Economic Commission for Africa (ECA), collaborating with the International Fund for Agricultural Development and other partners introduced a smart classroom equipped with an AI-enabled learning management system to train and provide farmers with access to training, resources, and knowledge on modern agricultural methods. The farm digitization involved a mobile crush pen, a digital scale, an RFID reader, ultrasonic scanning, record-keeping and report-generating software, an IoT-based small-stock health monitoring system, an IoT-based water intake monitoring system for small stock, and an online auction platform. The farm also focuses on improving stud genetics for small stocks, establishing a national registration system for goats and sheep, protecting local genetic resources, and managing rangeland.

By deploying smart agricultural technologies and providing targeted training, the initiative has empowered farmers to make data-driven decisions, improve resource management, and boost overall productivity. Water savings of more than 40 per cent have directly addressed water scarcity in the Kgalagadi District, while the integration of virtual fencing and precision feeding has improved animal welfare and herd performance.

Virtual fencing system has eliminated losses from predators and stray animals, directly protecting the farm's primary capital. By improving animal nutrition through precision feeding, the farm has seen a rise in fertility rates and overall herd productivity, solidifying its transformation from small stock development to a centre of excellence.

But productivity effects of digital agriculture have been uneven. ICT diffusion can accelerate information flows and market access, but these benefits remain limited unless complemented by skills and productive capabilities that enable adoption at scale. In practical terms, agriculture technology strategies are more likely to deliver sustained productivity gains when linked to skills development, extension systems, and agro-processing/industrial linkages that raise the returns to technology adoption.

HEALTH

Healthcare is one of the most promising fields for AI in Africa, given the acute shortages of medical professionals and resources. Many African countries have a low doctor-to-patient ratio (often fewer than one doctor per 5,000 people), and rural areas are especially underserved. Only seven African countries, including Cape Verde, Seychelles, Libya, Eswatini, Tunisia, Mauritius, and Algeria, have met the World Health Organization's recommended physician-to-population ratio. The continental average remains low, with just 2.6 physicians per 10,000 people, and the region is expected to see a shortage of 6.1 million healthcare workers in 2030.[68]

Digital health solutions—from AI diagnostic algorithms to predictive analytics—are improving healthcare delivery, diagnostics, and access. AI-assisted diagnostics and biometrics help improve access to healthcare for the 600 million Africans without access to healthcare services.[69] And IoT has been applied in healthcare and social services. For example, South Africa uses the IoT to collect patient information. This involves deploying sensors, wearable devices, and connected medical equipment that automatically record and transmit patient data directly to healthcare providers. And Rwanda has partnered with the American company, Zipline, to use drones for transporting blood and medical supplies to rural hospitals.[70] Frontier technologies such as drones are already improving healthcare systems' resilience, equity, and efficiency (box 3.3).

Adopting frontier technologies in Africa's health sector thus boosts economic growth by creating jobs, building digital skills, and improving healthcare efficiency. By streamlining the delivery of medical supplies and services, technologies like AI diagnostics, telemedicine, and drone logistics reduce operational costs and waste, increase system efficiency, and help mitigate the financial burden of healthcare on households and governments. Digital health solutions drive inclusive economic transformation and strengthen local tech industries.

Box 3.3 Zipline—reshaping healthcare logistics

Zipline, a pioneer in autonomous drone delivery, has reshaped healthcare logistics across Africa. Operating in Côte d'Ivoire, Ghana, Kenya, Nigeria, and Rwanda, Zipline delivers blood products, vaccines, insulin, antibiotics, and other essentials to hospitals and health centres. In Rwanda, the Muhanga distribution centre alone reaches more than 350 health facilities, offering a lifeline to remote areas. What once took four to five hours by road can now be achieved in just 45 minutes by drone, ensuring communities receive timely access to life-saving treatments.

Zipline has become a driver of economic transformation in the regions where it operates, with measurable effects on employment, revenue, income, and productivity. More than 500 local jobs have been created, a third of which are held by women, while hundreds of high-tech positions have also emerged, signalling a shift towards advanced skill development and technological capacity building. On the economic side, millions of dollars have been saved through supply chain efficiencies, including a 67 per cent reduction in wastage and a 60 per cent drop in stockout times. Health outcomes, such as a 56 per cent decline in maternal mortality and a 66 per cent decline in missed opportunities to treat malaria, highlight the indirect economic benefits of Zipline's services.

Scaling Zipline's model to a regional and continental level requires harmonizing drone regulations, investing in local talent development, and strengthening supply chain linkages to ensure efficiency and resilience.

FINANCE AND COMMERCE

Frontier technologies have enormous potential to support implementation of AfCFTA's Digital Trade Protocol. Fintech innovations, such as mobile money and blockchain, are expanding financial inclusion, providing millions with access to capital and secure payment systems. Digital payment systems also facilitate access to core financial services, including mobile transfers, mobile payments, and mobile banking. By 2024, the mobile money industry recorded 2.1 billion registered accounts with more than half a billion active users (514 million), with more than two-thirds of the registered accounts coming from Sub-Saharan Africa. Growth in active 30-day accounts was led by East Africa, contributing 32 per cent of new accounts in 2024.[71]

Kenya's M-Pesa stands out as a transformative financial innovation in the subregion since its launch in 2007, penetrating in nearly all sectors of the economy, including banking, retail, transport, utilities, and government, enabling a more integrated financial ecosystem.[72] M-Pesa's has improved financial inclusion, especially among the unbanked and underbanked, with nearly 83 per cent of Kenyans gaining access to formal financial services in just over a decade. By streamlining cross-border payments, optimizing supply chains, and enhancing transparency, fintech innovation reduces trade costs and improves competitiveness. At an international level, Jumia, also known as the "Amazon of Africa," is the largest e-commerce platform in Africa with operations in nine countries, including Nigeria, Kenya, Morocco, Algeria, Egypt, Ghana, Ivory Coast, Senegal, to Uganda (box 3.4).

Box 3.4 Jumia Africa's e-commerce platform

Jumia, established in 2012, has evolved into a transformative force by integrating frontier technologies into its operations, while addressing unique challenges of African markets. In 2024, Jumia reported 5.4 million active consumers, 70,000 active sellers, and 22.3 million orders, underscoring its scale and influence in shaping Africa's digital economy. The platform's marketplace is supported by its proprietary logistics arm, Jumia Logistics, and its fintech ecosystem, JumiaPay, which together enable seamless trade, delivery, and financial transactions. Through this model, Jumia demonstrates the practical application of artificial intelligence (AI), the Internet of Things (IoT), big data analytics, and emerging blockchain use, enhancing decision-making, personalizing customer experiences, and optimizing last-mile delivery.

Jumia has opened opportunities for entrepreneurs and small businesses with more than 100,000 small and medium enterprises using the platform. Its operations directly and indirectly support the creation of jobs: JForce, for example, has more than 40,000 sales agents operating in various countries. Expansion into rural Côte d'Ivoire has provided access to e-commerce in 107 towns through 181 pick-up stations. Surveys reveal that 90 per cent of rural buyers saved money, while 71 per cent intended to reorder, a sign of affordability and increased market integration.

Jumia has also introduced significant foreign investment and confirmed the continent's positioning in international digital markets. In 2024, the firm had revenues of $167.5 million, supported by approximately 12,000 cross-border sellers (mostly from China), which account for one-third of the items sold on the platform.

The platform also serves as an entrepreneurial enabler, providing SMEs and women's enterprises with access to national and regional markets. JumiaPay encourages digital payments and other credit products such as Buy Now, Pay Later for deeper financial inclusion that closes structural imbalances in financial markets on the continent.

Scaling Jumia's model across Africa requires addressing the persistent structural challenges that constrain its expansion, particularly underdeveloped logistics networks and high delivery costs. These challenges have forced Jumia to withdraw from certain countries where continued operations proved financially unsustainable. Expanding into additional countries will require harmonized regulations to ease customs bottlenecks, standardize tax regimes, and enable smoother cross-border e-commerce. At the same time, Jumia must deepen financial inclusion by growing JumiaPay services, Buy Now, Pay Later (BNPL) products, and seller credit programmes.

E-GOVERNMENT AND PUBLIC SERVICE DELIVERY

The overall trajectory of e-government development in Africa remains promising (table 3.4). And digitalization is advancing efforts to improve the efficiency, transparency, and accountability of government transactions and service delivery. Significant progress has been made in strengthening systems and infrastructure, laying the groundwork for an accelerated transition to e-government across the continent.

Table 3.4 African countries offering online service, 2022

	Countries	Percentage	Number of people benefit the online services (000)
Register a business	45	0.8	1,115,689
File company/business tax online	34	0.6	842,965
Submit income taxes	33	0.6	818,172
Apply for personal identity card	33	0.6	818,172
Pay for utilities (electricity/gas)	32	0.6	793,379
Apply for driver's license	30	0.6	743,793
Apply for building permit	31	0.6	768,586
Apply for land title registration	27	0.5	669,414
Pay for utilities (water)	33	0.6	818,172
Apply for environmental permit	22	0.4	545,448
Apply for social protection programmes	27	0.5	669,414
Apply for visa	23	0.4	570,241
Register a motor vehicle	10	0.2	247,931
Submit change of address	4	0.1	99,172

Source: ECA staff using data from UNDESA (2024).

More than 40 African countries provide digital platforms for business registration, while 34 countries offer online tax payment services—together covering nearly one billion people. And about half of the continent's countries have adopted digital platforms for local services such as utility payments (electricity, gas, water), building permits, and land title registration. For example, the South African Revenue Service has implemented an AI chatbot on its website to assist taxpayers with registration, filing, and refund inquiries, which has improved operational efficiency and reduced administrative delays. And Rwanda's IremboGov provides citizens and businesses with a single digital portal to access and pay for more than 100 government services (box 3.5)

Box 3.5 Rwanda's IremboGov e-government services

IremboGov, Rwanda's flagship e-government platform, was launched in 2015 as a public–private partnership between Irembo Ltd and the Government of Rwanda to digitize service delivery nationwide.

It transformed most paper-based services, which are fragmented across agencies and ministries, making access slow, expensive, and prone to leakages. Since its launch, IremboGov has processed more than 25 million applications, approximately $300 million in transactions, saving more than 100 million working hours and reducing the average service delivery time from five days to just 24 hours. In addition, 45 per cent of Irembo's users pay for services online, generating more than RwF 350 billion in revenue for the government. Each month, the platform process between 300,000 and 500,000 applications, with 80 per cent of transactions performed online.

Box table 3.5.1 Irembo in Rwanda's e-government from 2015 to 2023

	Before Irembo (pre-2015)	After IremboGov (2023)
Services digitized	<10%, siloed	>50% (more than 100 services integrated)
Applications processed	Limited by physical offices	8.4 million annually
Application time	Days/weeks	Hours / ~3 days (passports)
Payment method	Mostly cash	>97% digital
Citizen time saved	Minimal	~12–16 million hours saved/year
Support workload	Manual	Self-service share 41%
Revenue leakages	Higher risk	Digital audit trail; improved compliance
Jobs created (agents)	Few digital jobs	7,000+ Irembo agents

Source: ECA staff elaboration.

Rwanda's digital policy and comprehensive legal frameworks, such as the Data Protection Law and cybersecurity initiatives, underpin the platform's success. The Smart Rwanda Master Plan, along with a robust national ICT strategy that prioritizes digitization and integrated services, strengthen institutional capacity, enhance service efficiency, and improve accountability in public administration, while contributing to 100 per cent end-to-end digital government services.

Supporting Rwanda's digital transformation is the national biometric ID system, facilitating secure identification and authentication for online services. In addition, significant government investments in broadband infrastructure—including 4G LTE and fibre—have been made to achieve nationwide connectivity for digital government initiatives. Another enabler is the Irembo agent network of more than 7,000 agents, which extends access to citizens without smartphones or internet, further supporting financial inclusion.

Nevertheless, challenges including digital divide and literacy, technical gaps, payment failures, integration issues and concerns on trust and data security are hindering the comprehensive and successful implementation of this platform. The Government of Rwanda is addressing these issues through financing digital infrastructure and basic digital skills development, while bridging gaps in policy, regulation, and strategies for ICT accessibility and for long-term economic inclusion and resilience.

Scaling will require replicating the critical enablers that supported Rwanda's progress including clear digital policies, a secure identification system, strong institutional capacity, and reliable digital infrastructure, while tailoring them to local realities. Regional frameworks, particularly the African Union's Digital Transformation Strategy (2020–2030) and the Smart Africa Alliance, can provide common standards for interoperability, data protection, and cross-border trust in digital platforms. At the same time, partnerships with national governments will be essential to localize tax administration, land registration, and civil documentation. And capacity-building programs and agent networks can help bridge the digital divide and ensure inclusion for rural and less digitally literate populations.

Source: ECA staff based on official government documents.

ECA CASE STUDIES

ECA case studies demonstrate how frontier technologies contribute to economic transformation. Each one highlights the impact of the selected technology through changes in productivity, job creation, and investment, among other indicators, as well as the environment that enables the technology to be adopted and thrive. The criteria for selecting them include the level of maturity of the associated frontier technologies, and the speed and scale of their diffusion. The cases have generally reached advanced phases of diffusion and have attributes that enable fast and wide-scale diffusion. They show how frontier technologies can be quickly implemented with minimal resources to generate immediate high impact results. Annex 3.1 illustrates the core frontier technologies that underpin the selected cases, hence drive sectoral transformation, the determinants of their adoption, and the phase of diffusion of the technologies. It also shows the impact of the cases and the enabling environment that allows these technologies to scale up.

RENEWABLES IN MOROCCO

Aiming for 52 per cent renewable energy by 2030, Morocco is heavily investing in solar, wind, and hydroelectricity.

Renewable energy, especially solar and wind, is transforming Morocco's energy system and economy. Aiming for 52 per cent renewable energy by 2030, Morocco is heavily investing in solar, wind, and hydroelectricity. The 2009 National Energy Strategy aims to achieve 52 per cent renewable energy by 2030, and 70 per cent by 2050 through measures such as developing renewable energy sources, investing in energy efficiency, and integrating electricity markets across North Africa and Europe. Significant projects include the Moroccan Solar Plan with 2,000 MW from solar power by 2020 and 4,800 MW by 2030, the Wind Programme aiming for 2,000 MW by 2020 and 5,000 MW by 2030, $3.5 billion in grid infrastructure, and $700 million in pumped storage. To support such projects, Morocco is strengthening the National Agency for the Development of Renewable Energy and Energy Efficiency and the Moroccan Agency for Sustainable Energy through public–private partnerships.[73]

By 2023, Morocco's electricity mix shifted from a predominantly coal- and oil-based generation mix to a diversified generation integrating 4.8 per cent PV, a significant Concentrated Solar Power (CSP) plant, 15 per cent wind, and 1.2 per cent hydropower. Wind and solar now make up nearly 20 per cent. Future projects, such as the 2040 Master Plan (52 GW), Power-to-X (5 GW), and Green Hydrogen (20 GW), will further transform the sector. Government vision, policy reforms, conducive public and project finance, regional energy integration, establishing relevant energy sector institutions, solar and wind technology scaled adoption, and smart local content provisions enabled Morocco's transformational results. By optimizing the electricity fuel mix, expanding renewable energy sources (wind, solar, hydropower), enhancing energy efficiency, and strengthening regional market integration, the government has achieved significant developments, including 300 MW of wind energy for phosphate plants, 40 MW of solar power for Tangier Automotive City, 60 MW for Lafarge-Holcim Cement, 50 MW of solar and wind for steel decarbonisation, 1 MW for Marrakesh's electric buses, 50 MW for Tangier rail electrification, 10 MW for electric vehicle stations nationwide, 80 MW for solar-powered farm irrigation, and 20 MW of biomass for agriculture.[74] Renewables are enhancing production and efficiency across various sectors.

Morocco's renewable energy sector is projected to create nearly 449,000 jobs by 2030 and 483,000 by 2040.[75] Regional interconnection benefits include grid stability and increased exports—Morocco exported $20.3 million in electrical energy to Spain in 2024.[76]

INDEPENDENT POWER PRODUCERS IN SOUTH AFRICA

The Renewable Energy Independent Power Producer Procurement Programme was introduced as an innovative approach aimed at developing 17.8 GW of solar and wind from 2010 to 2030. It aimed to generate 7,090 MW across 97 projects and by March 2023, 89 projects were operational, supplying 6,105 MW.[77] The programme also reduced costs, with solar dropping from $0.34/kWh to $0.07/kWh. Several factors have supported the success of this programme, including a national renewable energy vision, an innovative procurement system, a large-scale initiative attracting private investment, staggered bidding windows providing long-term market signals, smart criteria that foster collateral benefits, institutional support, supportive policy, and a shift from expensive policies like feed-in tariffs to competitive bidding.

The programme has had notable socioeconomic effects as its design assigned a 30 per cent weight to development factors in bid evaluations and consideration of community needs within a 50 km radius, thereby enhancing social inclusion and benefits. The first three bids for solar and wind projects generated an estimated 20,000 temporary jobs and 35,000 operational jobs.[78] Since its inception, roughly R210 billion in investment has facilitated the participation of 120 IPPs, yielding significant economic impacts.[79] The initial bidding window attracted nearly $6 billion in renewable investments, with about $4.5 billion allocated.[80] This was followed by approximately $3.5 billion and $4.5 billion for 17 projects in the second and third bidding windows, respectively.

The programme enabled communities to own 5 per cent of renewable energy assets, mobilizing resources for education, health, and infrastructure. Project 90 by 2030 has empowered communities with an average stake of 12 per cent stake in projects playing a vital role in tackling South Africa's inequality. And by 2050, up to 30,000 marginalized individuals could access education, more than 3,000 enterprises could be supported, and 10,000 jobs could be created.[81]

To leverage the impact, South Africa established the Atlantis Special Economic Zone (SEZ) to develop a sustainable Greentech SEZ, attracting export investors and boosting local growth, employment, and manufacturing, and supporting suppliers and component manufacturers for the programme.[82] Companies such as ISOLAR, Gestamp Renewable Industries, and Resolux benefit from the zone, promoting the development of green technology.

However, challenges including licensing delays and bureaucratic hurdles that hinder investment, as well as coordination gaps in infrastructure development, which risk the stranding of assets. Furthermore, while aiming to boost growth, the programme primarily creates temporary, unskilled jobs and faces challenges in creating large-scale, permanent jobs.[83]

Wind farm at sunset, South Africa
© Adobe Stock

GREEN HYDROGEN IN NAMIBIA

Namibia aims to export hydrogen products, including ammonia, methanol, synthetic kerosene, and hot-briquetted iron, to markets in Europe, China, Japan, South Korea, and other regions worldwide. It aspires to create an at-scale green fuels industry with a production target of 10–12 million tonnes a year of hydrogen equivalent by 2050.[84] It also aspires to establish an integrated, thriving green ecosystem across Southern Africa by creating synergies in shared infrastructure, manufacturing collaboration, and power exports, as with South Africa, Botswana, Zambia and Angola.

The Green Hydrogen Programme is part of a green industrialization initiative characterized by an integrated and multisectoral approach that involves the power, industry, agriculture, and transport sectors, with participation from multiple ministries, including the Ministry of Mines and Energy and the Ministry of Industrialization and Trade.

Several programme components could benefit local communities through job creation:

- Producing electricity from renewable energy and using it to produce green hydrogen.
- Developing the iron and steel industry to diversify Namibia's economy through value addition to natural resources.
- Producing ammonia used in fertilizer to boost agricultural productivity, including in greenhouses.
- Applying hydrogen in the transport sector, including shipping with the goal of positioning Namibian ports as hydrogen fueling hubs, as well as using hydrogen to power heavy vehicles.

It is estimated that the hydrogen industry would add $4.1 billion (in real 2022 dollars) to Namibia's GDP by 2030, representing a 32 per cent increase over the GDP estimate without a hydrogen industry. By 2040, it could generate an additional $6.1 billion, 32 per cent higher than current GDP estimates. The hydrogen industry would also expand the domestic labour market, creating an estimated 280,000 jobs by 2030 and 600,000 jobs by 2040. Local manufacturing of wind turbine towers and blades could contribute $7 billion to the GDP by 2035–40. These activities are also expected to create an additional 7,000 direct jobs annually. Localizing solar cell and module manufacturing could contribute $4 billion to the GDP by 2035–40 and create 4,000 direct jobs annually by 2040.[85]

Green hydrogen development and green industrialization require strengthening the country's power infrastructure. So, Namibia is expanding its energy infrastructure to achieve universal electricity access by 2040 and to meet rising demand amid challenges such as severe droughts that impede imported hydropower. The government has implemented strategic policies outlined in its National Renewable Energy Policy, resulting in a surge in the installation of solar panels to 155 MW of installed solar capacity in 2024 from virtually zero a decade ago. The government also recognizes the need for a robust and well-adapted rail infrastructure to support efficient iron ore transportation. So, potential upgrades and extensions of the rail network are under discussion to bolster connectivity with neighbouring countries and enhance its role as a transport corridor.[86]

To promote green hydrogen development and green industrialization, the government is forging robust public-private partnerships and developing appropriate regulatory frameworks to support these initiatives, including the introduction of national sustainable special economic zones policy in October 2022. Similarly, the Ministry of Industrialization and Trade seeks to integrate green technologies in areas such as steel manufacturing and charcoal production, and adapting existing policies to support this transition, including the country's automotive sector policy and its mineral beneficiation strategy. On a global scale, Namibia is fostering strategic partnerships in green hydrogen and critical raw materials with international entities, including the European Union (EU), Germany, and Japan. Domestic talent sourcing and attractive immigration policies will ensure a sufficient labour supply. The government is also establishing a facility to mobilize concessionary climate finance, aiming to de-risk investments and reduce the cost of capital for hydrogen projects.[87]

ELECTRIC VEHICLE DEVELOPMENT IN MOROCCO

Morocco has emerged as a regional leader in EV adoption, propelled by ambitious national policies, an expanding renewable energy industry, and significant investments in charging infrastructure. In 2023, electric vehicles represented 4.5 per cent of the Moroccan automobile market, with 7,165 units sold out of a total of 161,504 vehicles, resulting in a substantial 25.3 per cent rise in electric vehicle sales compared to 2022, indicating a discernible trend in the Kingdom.[88] Morocco has an annual production capacity of approximately 700,000 vehicles, including 70,000 electric cars, anticipated to grow to around 1 million by the end of 2025, including 100,000 electric cars.[89]

The EV market in Morocco is projected to post a compound annual growth rate of 10.8 per cent, resulting in a projected market value of $163.4 million by 2029.[90] This increase is expected to lead to developing charging infrastructure, create jobs, and save foreign exchange. The projected shift to EVs would decrease carbon emissions to approximately 2.6 Mteq CO2 per year by 2050 (compared with around 30 Mteq CO2 per year emitted by cars in 2050 in a business-as-usual scenario) and reduce hydrocarbon demand by around 2 billion litres of fuel each year.[91]

Morocco's 2014–20 Industrial Acceleration Plan and its successors aim to tactically stimulate the establishment of the country's automotive industry as well as the development of automotive cities such as Kenitra and Tangier. The surge in the adoption of electric vehicles in Morocco is motivated by government incentives, including complete exemption from customs taxes and VAT, purchasing incentives, and a discounted electricity tariff at night.[92] These incentives aim to reduce the costs associated with acquiring and using EVs, thereby increasing accessibility and promoting their adoption. Morocco's *National Electric Mobility Development Plan 2021–30* aims to have 150,000 electric vehicles on the road by 2030. The plan aims to strengthen the charging infrastructure for EVs, including through public private partnerships (PPP), reduce pollution, establish a novel industrial and economic sector, and reduce dependence on fossil fuels. Morocco's Investment Charter outlines support mechanisms to enhance the Kingdom's investment climate, establishing it as a continental and international hub for foreign direct investment.[93] Electric mobility, semiconductors, and renewable energy are among the segments that benefit from support under the Investment Charter. As of 2024, Morocco had around 1,600 stations for electric vehicles.[94]

The Oxford Business Group estimated that the auto industry accounted for 19 per cent of Morocco's GDP in 2019 (both internal combustion engine and electric vehicles combined), making the automotive sector a pillar of the Moroccan economy, with a significant contribution to exports and employment in the country. More than 220,000 people work in the sector.[95] The country's strategic location at the intersection of Europe and Africa enables it to access both markets efficiently, with Tangier Med, a Moroccan port located near Spain. Of the 20 greatest vehicle manufacturers from Europe, Asia, and America, 11 are in the Tangier Med Zone. The Tangier Med platform hosts an ecosystem of global automotive operators, comprising more than 150

An EV parked on the roadside while recharging in Morocco
© Adobe Stock

Tier 1, 2, and 3 suppliers,[96] which generate more than 40,000 direct jobs and represent an investment volume exceeding $4 billion.[97]

AERIAL CABLE TRANSPORT IN MADAGASCAR AND RWANDA

Cable cars contribute to the vision of sustainable, green, climate-resilient urban mobility infrastructure in Africa. They are green infrastructure assets that offer both impact and returns, constituting a scalable model of low-carbon, inclusive public transport that cities across Africa can emulate. Cable cars are used for tourism and urban transport in African countries such as Algeria and South Africa. Other countries on the continent, such as Madagascar and Rwanda, are embracing cable cars to address urban mobility challenges.

The Malagasy capital, Antananarivo, faces numerous urban planning and transportation challenges. It is subject to a highly dynamic and difficult-to-manage urban growth, with about 4.3 million people living in the urban area,[98] up from about 175,000 in 1950.[99] It is characterized by steep hills and a plain primarily covered by rice fields, posing significant challenges for urban planning and population mobility, particularly given the extremely low density of the city's road network. The average one-way journey in Antananarivo takes 46 minutes, with economic costs of traffic congestion estimated to result in an annual loss of approximately $40 million or 0.34 per cent of GDP, while in other secondary cities it is estimated to be 15–25 minutes.[100]

A cable transportation system in Antananarivo provides a solution to traffic congestion and pollution, and it is more cost-effective. It is capable of transporting between 2,200 and 2,800 passengers per hour in each direction. The high hourly capacity translates to an estimated daily capacity ranging from 40,000 to 80,000 passengers on some of the most frequently used routes in the city, including routes to educational and university complexes, business centres, administrative centres, and tourist areas.[101] The system cost 152 million euros, financed by France through a loan to the government of in 2021.

The benefits of the cable transport system include a significant reduction in CO2 emissions due to its electric power and the removal of approximately 2,000 cars from the road network per day, equivalent to 2.6 tons of CO2 per day. Other benefits include time savings for passenger efficiency in overcoming topographical and urban obstacles (such as hills and rice fields), guaranteed service regularity with a fully dedicated site, the opportunity for passengers to enjoy a pleasant travel experience with panoramic views, and many jobs are created in implementing the system (construction, operation, maintenance etc.).

In Kigali, plans are under way to develop a 5.5 km mobility initiative valued at $100 million to ease the city's traffic congestion, reduce greenhouse gas emissions, and connect underserved communities to jobs and essential services. Construction is expected to begin in 2026, with commissioning scheduled for 2028. Once complete, the cable system will convey more than 50,000 passengers a day on a 15-minute

Antananarivo cityscape, Tana, capital of Madagascar
© Adobe Stock

end-to-end journey, integrating with the city's existing transport infrastructure. The project—anchored in Rwanda's Green Taxonomy, E-mobility Strategy, and Climate and Nature Finance Strategy—aligns closely with national climate objectives, which target a 38 per cent reduction in carbon emissions by 2030 and carbon neutrality by 2050.

POLICY DIRECTIONS

The ongoing transformation of Africa's economic and social landscape by frontier technologies—ranging from artificial intelligence and blockchain to renewable energy, is influencing Africa's economic and social development across sectors including agriculture, health, transport, energy, finance. While these technologies are altering established practices and systems, they also present challenges.

The findings here caution against uniform frontier technology strategies across sectors, underscoring the need for differentiated approaches tailored to sector-specific production structures and absorptive capacity. The productivity effects of frontier technologies vary systematically depending on how production is organized, the skill intensity of activities, and the presence of complementary industrial and institutional capabilities. In sectors characterized by fragmentation, informality, and weak firm capabilities—such as smallholder agriculture or informal services—technology adoption often yields weak or even negative productivity effects when deployed in isolation, reflecting adjustment costs, coordination failures, and limited capacity to absorb and scale new tools. By contrast, sectors with more structured production systems, stronger firm linkages, and clearer pathways for learning-by-doing—such as manufacturing, agro-processing, and digitally enabled services—are better positioned to translate frontier technologies into sustained efficiency gains.

The findings here caution against uniform frontier technology strategies across sectors, underscoring the need for differentiated approaches tailored to sector-specific production structures and absorptive capacity.

These differences imply that sectoral technology strategies must be sequenced and designed differently. In lower-productivity, labour-intensive sectors, priority should be placed on foundational investments in skills, extension systems, organizational capacity, and basic infrastructure before or alongside technology deployment. In more capital- and knowledge-intensive sectors, frontier technologies can be leveraged earlier to accelerate upgrading, if industrial capacity and workforce skills are already in place. Treating frontier technologies as sector-neutral inputs risks misallocating resources, amplifying inequalities between sectors, and generating disappointing aggregate outcomes. A differentiated, sector-aware approach is thus essential to ensure that frontier technologies contribute meaningfully to productivity growth, employment creation, and structural transformation across African economies.

ANNEX 3.1

Case Study	Core Frontier Technologies	Determinants of technology adoption	Phase of Diffusion	Impact	Enabling Environment
Morocco Renewable Energy Transition	• Photovoltaics • Hydrogen and ammonia for power • Advanced data analytics	• Accessibility • Scalability • Compatibility with existing systems • Observability of outcomes of the technology used by others	• Phase 4: scaling up and market consolidation	• By 2023 electricity generation included 4.8% PV, 15% wind and 1.2 % hydropower, with wind and solar making up nearly 20% • Nearly 449,000 jobs by 2030 and 483,000 by 2040 in renewable energy production • Expected exports of nearly $36 million to Spain with 461 GWh	• Government vision and policy reforms • Conducive public and project finance • Energy integration initiatives between Europe and North Africa • Establishing energy sector institutions • Scaled technological adoptions • Sectorial applications for renewable energy
South Africa - Renewable Energy Independent Power Producer Procurement Program (REIPPPP)	• Photovoltaics	• Relative advantage over coal from an environmental perspective • Ease of use • Accessibility • Compatibility with existing systems • Observability of outcomes of the technology used by others	• Phase 4: scaling up and market consolidation	• Attracted nearly $6 billion investment in renewable energy • 89 projects operational, supplying 6,105 MW • Community owns 5% of the renewable energy assets; average stake of 12% in project ownership • Reduced cost of electricity from $034/kWh to $0.07/kWh • 20,000 temporary and 35,000 operational jobs created	• National renewable energy vision • Supportive policy and institutions • Innovative procurement systems • Initiatives attracting private investments • Long-term market signals and smart criteria that fosters collateral benefits • Establishment of Special Economic Zones •
The Green Hydrogen Programme in Namibia	• Hydrogen and ammonia for power • Photovoltaics • Critical minerals extraction and processing • Continuous flow chemical synthesis • Advanced data analytics	• Accessibility • Scalability • Observability of outcomes of the technology used by others	• 2/Phase 3: • Strategy and infrastructure development/ pilot implementation Phase	• About 208,000 jobs created by 2030 and 600,000 by 2040 • $4.1 billion GDP contribution by 2030 (increasing GDP by 32%) • Solar power generation increased from a baseline of zero to 155MW installed capacity • Expected local manufacturing contribution of $7 billion to the GDP by 2035-40 and generate 7,000 direct jobs annually • Expected localizing solar cell and module manufacturing contribution of $4 billion to the GDP by 2035-40 and create 4,000 direct jobs by 2040	• Implementations of strategies and policies • Infrastructures provision that support raw material transportation • Forging robust public-private partnership and regulatory frameworks • Fostering strategic international partnerships • Establishing a facility to mobilize concessionary climate finance (de-risk investments and cost of capital)
Electric Vehicles	• Electric batteries • Advanced Integrated Circuit design & fabrication • Advanced magnets	• Accessibility • Scalability • Compatibility with existing systems • Observability of outcomes of the technology used by others	• Phase 4: scaling up and market consolidation	• Projected market value of $163.4 million by 2029 in Morocco • Auto industry accounted for 19% of Morocco's GDP in 2019 • Decrease carbon emissions to approximately 2.6 Mteq CO2 per year by 2050 • Reduce hydrocarbon demand by around 2 billion litres of fuel each year • Expected 150,000 EV Market growth by 2030 • More than 220,000 people work in the export of EVs in Morocco in 2025 • The Tangier Med platform generates over 40,000 direct jobs and represents an investment volume exceeding $4 billion	• National Policies and incentives to promote EV adoption • Industrial Acceleration Plan and Investment Charter to establish manufacturing hubs • Investment in ports and logistics • Significant investment in charging infrastructure • Government incentives

Case Study	Core Frontier Technologies	Determinants of technology adoption	Phase of Diffusion	Impact	Enabling Environment
Aerial Cable Transport	• Advanced composite materials • Coatings • Electric batteries (supporting)	• Relative advantage over coal from an environmental perspective • Observability of outcomes of the technology used by others	• Phase 2: Strategy and infrastructure development	• Influence daily commuting patterns (an estimated daily capacity ranging from 40,000 to 80,000 passengers) • Reduced traffic congestion in the city (removal of approximately 2,000 cars from the road network per day, equivalent to 2.6 tons of CO2 per day) • Time savings for travellers • Opportunity for tourist attraction	• Sustainable urban mobility vision • Government support through loan emphasizing modernization • Integration of mobility with urban planning
Smart Agriculture in Botswana	• Artificial intelligence (AI) • Machine learning • Advanced data analytics • Photonic sensors • Autonomous systems operation technology • Advanced radiofrequency communications	• Accessibility • Scalability • Observability of outcomes of the technology used by others	• Phase 3: • Pilot implementation Phase •	• Strengthened climate resilience and resource efficiency (water savings of over 40%) • Eliminated (100% reduction) losses from predators and stray animals. • Boosted fertility rates and overall herd productivity. • Increased export revenue and strengthened trade balance. • Created stable employment opportunities, diversifying rural livelihoods. • Empowered decision-making capacity for farmers	• Integrated digital infrastructure and AI-enabled capacity building • Enabling policy environment aligned with national development strategies • Strategic public–private partnerships • Clear regulatory frameworks • Access to specialized agri-tech innovation and digital market linkages
Zipline	• Autonomous systems (Drones) • Advanced radiofrequency communications (incl. 5G) • Artificial intelligence (AI) • Advanced data analytics	• Scalability • Observability of outcomes of the technology used by others	• Phase 4: scaling up and market consolidation	• More than 500 local jobs created • The Muhanga distribution centre in Rwanda reaches more than 350 health facilities • Millions of dollars saved through supply chain efficiency (a 67% reduction in wastage and a 60% drop in stockout times) • In rural areas, household incomes rose by as much as 67% • A 56% reduction in maternal mortality and a 66% decrease in missed opportunities to treat malaria	• Robust digital infrastructure • Enabling policy environment, and institutional capacity • Clear regulatory frameworks • Access to finance for the wider logistics and healthcare supply chain • Harmonized regional drone regulations, talent development, and supply chain integration • Public–private partnerships
M-Pesa	• Advanced radiofrequency communications • Advanced data analytics • Protective cybersecurity technologies	• Accessibility • Scalability • Observability of outcomes of the technology used by others	• Phase 4: scaling up and market consolidation	• Expanded financial inclusion, with nearly 83% of Kenyans gaining access to formal financial services within just over a decade.	• Progressive "test-and-learn" regulatory environment • Advanced frontier technology stack • AI-driven credit scoring, enabling instant, unsecured micro-loans • Integration with National Digital ID systems • Interoperable digital payment rails • Alignment with regional payment frameworks
Jumia	• Artificial intelligence (AI) • Advanced data analytics • Machine learning • Advanced radiofrequency communications • Protective cybersecurity technologies	• Accessibility • Scalability • Observability of outcomes of the technology used by others	• Phase 4: scaling up and market consolidation	• Enabled digital commerce for 5.4 million consumers and 70,000 sellers, supporting 100,000+ SMEs. • Processed 22.3 million orders with $1.1 billion GMV in 2024. • Created income opportunities for 40,000+ sales agents and logistics workers. • Expanded rural access through 181 pick-up stations in 107 towns, with 90% of rural users reporting cost savings. • Strengthened Africa's integration into global e-commerce via 12,000 cross-border sellers and $167.5 million revenue (2024	• Digital Ecosystem • Entrepreneurship & Innovation • Financial Inclusion • Global Market Linkages • Frontier Tech Integration

Case Study	Core Frontier Technologies	Determinants of technology adoption	Phase of Diffusion	Impact	Enabling Environment
Rwanda's IremboGov E-government Services	• Advanced radiofrequency communications • Artificial intelligence (AI) • Advanced data analytics • Protective cybersecurity technologies • Natural language processing	• Relative advantage over existing solutions • Ease of use • Compatibility with existing systems • Observability of outcomes of the technology used by others • Accessibility • Scalability		• Reduced average service delivery time from 5 days to 24 hours, with passport issuance dropping to approximately 3 days. • Saved citizens over 100 million working hours (approx. 12–16 million hours annually) by digitizing manual processes. • Mobilized over RwF 350 billion in government revenue, securing significantly higher compliance with >97% of payments now fully digital. • Created 7,000+ new jobs through the Irembo agent network, extending economic access to non-digital users. • Scaled service delivery from <10% to >50%, integrating over 100 government services into a single platform. • Processed over 25 million applications since launch, with an annual volume of 8.4 million and transaction value exceeding $300 million.	• Comprehensive legal frameworks and national strategies ensuring trust and standardization • Strategic Public-Private Partnership model driving service innovation and inclusive agent networks • Digital public infrastructure anchored by a national biometric ID system broadband connectivity
Hawasa Industrial Park	• Coatings • High-specification machining processes • Continuous flow chemical synthesis • Advanced data analytics • Photovoltaics • Photonic sensors • Autonomous systems operation technology	• Relative advantage over existing solutions • Ease of use • Observability of outcomes of the technology use by others • Affordability and scalability	• Phase 4: scaling up and market consolidation	• Job creation - 25,000 to 35,000 • 90% water recycling • Increases in efficiency and productivity • Increased export earnings – up to $44 million	• Strong government ownership • Clear industrial and export-led manufacturing strategy • Sustainability and compliance features • One-stop shop services that reduce bureaucracy • Ready factory sheds and core onsite infrastructure

REFERENCES

6Wresearch. 2023. *Africa IoT Market (2025–2031).* 6Wresearch, July. https://www.6wresearch.com/industry-report/africa-iot-market.

Abraham, C., A. Rix, I. Ndibatya, and M. Booysen. 2021. "Ray of Hope for Sub-Saharan Africa's Paratransit: Solar Charging of Urban Electric Minibus Taxis in South Africa." *engrXiv.* https://doi.org/10.31224/osf.io/q9cwg.

Adeyeye, K. A., N. Ijumba, and J. S. Colton. 2021. "A Techno-Economic Model for Wind Energy Costs Analysis for Low Wind Speed Areas." *Processes* 9 (8): 1463. https://doi.org/10.3390/pr9081463.

Africa CDC (Africa Centres for Disease Control and Prevention). 2023. "A Six-Year Journey: Advancing Pathogen Genomics in Africa." April 4. https://africacdc.org/news-item/a-six-year-journey-advancing-pathogen-genomics-in-africa/.

African Union. 2024. *Continental Artificial Intelligence Strategy: Harnessing AI for Africa's Development and Prosperity.* African Union, Addis Ababa. https://au.int/sites/default/files/documents/44004-doc-EN-_Continental_AI_Strategy_July_2024.pdf.

AU (African Union). 2020. *The Digital Transformation Strategy for Africa (2020–2030).* African Union, Addis Ababa. https://au.int/sites/default/files/documents/38507-doc-DTS_for_Africa_2020-2030_English.pdf.

Baker, L., J. Burton, C. Godinho, and H. Trollip. 2015. *The Political Economy of Decarbonisation: Exploring the Dynamics of South Africa's Electricity Sector.* Energy Research Centre, University of Cape Town, Cape Town.

Blewett, D. 2025. "Wind Turbine Cost: How Much? Are They Worth It in 2026?" https://weatherguardwind.com/how-much-does-wind-turbine-cost-worth-it/.

BloombergNEF. 2024. *Energy Transition Factbook 2024.* BloombergNEF. https://assets.bbhub.io/professional/sites/24/Clean-Energy-Ministerial-Factbook-2024.pdf.

Boubker, O., M. Lakhal, Y. Ait Yassine, and H. Lotfi. 2024. "Towards Sustainable Transport in the Moroccan Context: The Key Determinants of Electric Cars Adoption Intention." *World Electric Vehicle Journal* 15 (4): 136. https://doi.org/10.3390/wevj15040136.

Buckholtz, A. 2020. "New Nigerian Biobank Advances Africa's Genomic Revolution." https://www.ifc.org/en/stories/2020/i14-54gene.

Chainalysis. 2023. *The Blockchain Data Platform.* Chainalysis. https://www.chainalysis.com/.

Coetzee, H., and A. Stoffberg. 2024. *CV VC African Blockchain Report 2024.* Absa Corporate & Investment Banking. https://cib.absa.africa/wp-content/uploads/2025/10/Africa-Blockchain-Report-2024_Digital.pdf.

CSIR (Council for Scientific and Industrial Research). 2022. "The National Centre for Nano-Structured Materials (NCNSM)." https://csirnano.co.za/about-us/.

Daily Trust. 2022. "Nigerian Lecturers Design AI Model, Nanomaterials to Tackle Health Crises." https://dailytrust.com/nigerian-lecturers-design-ai-model-nanomaterials-to-tackle-health-crises/.

Denebola Technologies. 2024. "Denebola: Bridging Healthcare Gaps." MIT Solve, April 23. https://solve.mit.edu/solutions/86048.

Distor, C. B., I. C. Ruas, T. Isagah, and S. B. Dhaou. 2023. *Emerging Technologies in Africa: Artificial Intelligence, Blockchain, and Internet of Things – Applications and Way Forward.* United Nations University. https://collections.unu.edu/eserv/UNU:9381/Distor_2023_Emerging_Tech_in_Africa_-_AI__Blockchain_and_IoT.pdf.

ECA (United Nations Economic Commission for Africa). 2022. "Accessible and Affordable Energy Should Underpin Africa's Just Transition." https://www.uneca.org/eca-events/stories/accessible-and-affordable-energy-should-underpin-africas-just-transition.

ECA (United Nations Economic Commission for Africa). 2026. *Advancing Electric Mobility in Africa: Context and Strategic Imperatives.* ECA, Addis Ababa.

Eghosa, F. 2025. "African Nations Meeting WHO's Doctor-to-Population Ratio (2000–2024)." *Intelpoint,* March 24. https://intelpoint.co/blogs/african-nations-who-doctor-ratio-2000-2024/.

El Hafdaoui, H., A. Khallaayoun, and S. Al-Majeed. 2025. "Renewable Energies in Morocco: A Comprehensive Review and Analysis of Current Status, Policy Framework, and Prospective Potential." *Energy Conversion and Management: X* 26: 100967. https://doi.org/10.1016/j.ecmx.2025.100967.

Elzoghby, A. O. 2019. "Pharmaceutical Nanotechnology in Egypt: Diverse Applications and Promising Outcomes." *Nanomedicine* 14 (6): 649–653. https://doi.org/10.2217/nnm-2018-0426.

FAO (Food and Agriculture Organization of the United Nations). 2024. "FAO Adds to Data Coverage of Employment in Agrifood Systems." November 1. https://www.fao.org/newsroom/detail/faostat-afs-employment-data/en.

FSD Kenya. 2019. *Kenya Annual Report 2019.* FSD Kenya, Nairobi. https://www.fsdkenya.org/wp-content/uploads/2020/06/FSD-Kenya-Annual-Report-2019.pdf.

Gilbert, P. 2025. "AI a Top Priority for African Execs in 2025 – BCG." *Connecting Africa,* January 16. https://www.connectingafrica.com/ai/ai-a-top-strategic-priority-for-african-execs-in-2025-bcg.

Global Solar Council. 2025. *Africa Market Outlook for Solar PV 2025–2028.* March 12. https://www.globalsolarcouncil.org/resources/africa-market-outlook-for-solar-pv-2025-2028/.

Global Wind Energy Council. 2025. *The Global Voice of the Wind Industry.* September 12. https://www.gwec.net/.

Government of the Republic of Namibia. 2022. *African Green Hydrogen Report 2025.* Government of the Republic of Namibia, Windhoek. https://ptx-hub.org/wp-content/uploads/2025/06/African-Green-Hydrogen-Report-2025.pdf.

Grand View Research. 2025. *Biotechnology Market Size and Share | Industry Report, 2030.* Grand View Research. https://www.grandviewresearch.com/industry-analysis/biotechnology-market.

GSMA Intelligence. 2024. *The Mobile Economy Sub-Saharan Africa 2024.* GSMA Intelligence, November. https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-economy/.

Iderawumi, M. 2025. "South Africa and China Establish 12,900 km Quantum Satellite Link." *Space in Africa,* March 20. https://spaceinafrica.com/2025/03/20/south-africa-and-china-establish-12900-km-quantum-satellite-link/.

IEA (International Energy Agency). 2014. *Africa Energy Outlook.* IEA, Paris. https://www.icafrica.org/fileadmin/documents/Knowledge/Energy/AfricaEnergyOutlook-IEA.pdf.

IEA (International Energy Agency). 2017. "Circulation Tax Exemption Morocco." November 5. https://www.iea.org/policies/6993-circulation-tax-exemption-morocco.

IEA (International Energy Agency). 2024a. *The Future of Geothermal Energy.* IEA, Paris. https://www.iea.org/reports/the-future-of-geothermal-energy/global-geothermal-potential-for-electricity-generation-using-egs-technologies.

IEA (International Energy Agency). 2024b. *Global EV Outlook 2024: Analysis.* IEA, Paris. https://www.iea.org/reports/global-ev-outlook-2024.

IEA (International Energy Agency). 2025a. *Trends in Electric Car Markets – Global EV Outlook 2025 – Analysis.* IEA, Paris. https://www.iea.org/reports/global-ev-outlook-2025/trends-in-electric-car-markets-2.

IEA (International Energy Agency). 2025b. *Tracking SDG7: The Energy Progress Report, 2025.* IEA, Paris. https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2025.

IOA (In On Africa). 2025. "Africa's Growing Energy Storage Capacity Is Key to Energy Self-Sufficiency." March 18. https://www.inonafrica.com/2025/03/18/africas-growing-energy-storage-capacity-is-key-to-energy-self-sufficiency/.

IRENA (International Renewable Energy Agency). 2024. *Renewable Power Generation Costs in 2024.* IRENA, Abu Dhabi. https://www.irena.org/Publications/2025/Jun/Renewable-Power-Generation-Costs-in-2024.

IRENA (International Renewable Energy Agency) and AfDB (African Development Bank). 2022. *Renewable Energy Market Analysis: Africa and Its Regions.* IRENA and AfDB, Abu Dhabi and Abidjan. https://www.irena.org/publications/2022/Jan/Renewable-Energy-Market-Analysis-Africa.

ITEdgeNews. 2024. "Unlocking Africa's AI Potential." March 12. https://www.itedgenews.africa/unlocking-africas-ai-potential/.

ITU (International Telecommunication Union). 2024. *ITU DataHub Dashboards.* ITU, Geneva. https://datahub.itu.int/dashboards/.

Laabi, T. 2017. *Case Study on Policy Reforms to Promote Renewable Energy in Morocco.* United Nations Economic and Social Commission for Western Asia (ESCWA), January. https://www.unescwa.org/publications/case-study-policy-reforms-promote-renewable-energy-morocco.

Labuschagne, H. 2025. "Massive Batteries Coming to South Africa." February 17. https://mybroadband.co.za/news/energy/582476-massive-batteries-coming-to-south-africa.html.

Leung, J., B. Neves, M. Romani, and A. Graham. 2024. *Localizing Green Industries in Namibia.* Green Hydrogen Business Alliance. https://green-hydrogen-business-alliance.de/download/report-localizing-green-industries-in-namibia/.

Madu, N., L. Ezenwa, P. Adebayo, and T. Mugume. 2024. *AI Startups Mapping in Africa.* FlippingBook. https://online.flippingbook.com/view/783480578?sharedOn=.

Mahia, R., and R. De Arce. 2020. "On the Economic Effects of a RES Local Industry Deployment in Morocco: A Case Study Defining Scenarios from a Survey to Stakeholders." *Sustainability* 12 (17): 6811. https://doi.org/10.3390/su12176811.

Market Data Forecast Ltd. 2025. *Middle East & Africa Nanomedicine Market Size Report, 2033.* September 11. https://www.marketdataforecast.com/market-reports/middle-east-and-africa-nanomedicine-market.

Matchaya, G., G. Y. Ebrahim, M. Aheeyar, O. C. Ajayi, and O. Ajilore. 2025. *Advancing Digital Agriculture for Climate Resilience and Economic Transformation in Malawi.* International Water Management Institute (IWMI). https://doi.org/10.5337/2025.219.

Matimba, V. 2025. "Event Recap: African Languages, Linguistic Complexity, and Ethical and Inclusive AI." MERL Tech. https://merltech.org/event-recap-african-languages-linguistic-complexity-and-ethical-and-inclusive-ai/.

McKinsey & Company. 2025. *Africa's Gen AI Potential.* McKinsey & Company. https://www.mckinsey.com/featured-insights/week-in-charts/africas-gen-ai-potential.

Ministry of Transport and Logistics (Ethiopia) and Ministry of Industry (Ethiopia). 2025. *Ethiopia E-Mobility Strategy and Implementation Plan (2025–2030).* Government of Ethiopia, Addis Ababa. https://www.motl.gov.et/sites/default/files/resource/V4_Oct%2010_E-mobility%20Strategy%20and%20Implementation%20Plan.pdf.

Mobility Foresights Pvt Ltd. 2025. *Africa Genomic Medicine Market Size and Forecasts 2031.* Mobility Foresights, August 11. https://mobilityforesights.com/product/africa-genomic-medicine-market.

Mordor Intelligence. 2025. *Nanotechnology Market Size & Share Analysis – Growth Trends & Forecasts (2025–2030).* Mordor Intelligence, July 2. https://www.mordorintelligence.com/industry-reports/nanotechnology-market.

Nkosi, T. 2025. "The Growth of EV Sales in Africa: Latest Figures." *EV24.Africa,* May 6. https://www.ev24.africa/the-growth-of-ev-sales-in-africa-latest-figures/.

North Africa Post. 2025. "Tesla Sets Foot in Morocco, Gateway to African & Mediterranean Markets." https://northafricapost.com/87913-tesla-sets-foot-in-morocco-gateway-to-african-mediterranean-markets.html.

Ntuli, N., and S. Helgenberger. 2019. *COBENEFITS of the New Energy World of Renewables for the People in South Africa.* https://www.cobenefits.info/wp-content/uploads/2019/10/COBENEFITS-Study-South-Africa-Economic-Prosperity-Kopie.pdf.

Ochola, R. 2025. "The Case for Genomic Surveillance in Africa." *Tropical Medicine and Infectious Disease* 10 (5): 129. https://doi.org/10.3390/tropicalmed10050129.

Precedence Research. 2025. *Biotechnology Market Size to Hit USD 5.71 Trillion by 2034.* July 15. https://www.precedenceresearch.com/biotechnology-market.

PwC (PricewaterhouseCoopers). 2017. *Sizing the Prize: What's the Real Value of AI for Your Business and How Can You Capitalise?* PwC. https://www.pwc.com.au/government/pwc-ai-analysis-sizing-the-prize-report.pdf.

PwC (PricewaterhouseCoopers). 2020. "Blockchain Technologies Could Boost the Global Economy US$1.76 Trillion by 2030—Track, Trace, Trust." https://www.pwc.com/gx/en/news-room/press-releases/2020/blockchain-boost-global-economy-track-trace-trust.html.

Qureca Spain. 2025. *Quantum Initiatives Worldwide 2025.* July 9. https://www.qureca.com/es/quantum-initiatives-worldwide/.

Raithatha, R., and G. Storchi. 2025. *The State of the Industry Report on Mobile Money 2025.* GSMA (Global System for Mobile Communications Association), London. https://www.gsma.com/sotir/wp-content/uploads/2025/04/The-State-of-the-Industry-Report-2025_English.pdf.

Razafimanantsoa, V., and Africanews. 2024. "Madagascar's Capital Launches Cable Cars to Ease Traffic Jam." *Africanews,* June 23. https://www.africanews.com/2024/06/23/madagascars-capital-launches-cable-cars-to-ease-traffic-jam/.

Rodrigue, J.-P. 2024. *The Geography of Transport Systems.* 6th ed. Routledge, London. https://doi.org/10.4324/9781003343196.

SciDev.Net Staff. 2017. "Nanotech Holds Promise for Africa, but Not Prioritised." https://www.scidev.net/sub-saharan-africa/news/nanotech-africa-prioritised/.

Siemens. 2025. *Siemens Newsroom.* Siemens Digital Industries Software. https://news.siemens.com/en-us/.

Siyobi, B. 2023. "SA's Renewable Energy Independent Power Producer Procurement Programme: Where to from Here?" *Good Governance Africa,* December 13. https://gga.org/the-state-of-the-renewable-energy-independent-power-producer-procurement-programme-where-to-from-here/.

Smith, T. 2023. "How Much Renewable Has REIPPPP Put on the SA Grid?" *ESI-Africa,* December 1. https://www.esi-africa.com/renewable-energy/how-much-renewable-has-reipppp-put-on-the-sa-grid/.

Spurt. 2024. *State of Artificial Intelligence in Africa.* https://assets.ctfassets.net/3iokqrmzb31b/6oWY1PPSe5ZRtfabJBSi4G/ac0db4e21ecceebd90018014f64a5fc0/State_of_Artificial_Intelligence_in_Africa.pdf.

Tanger Med. 2026. *Tanger Automotive City: Automotive Industry Hub.* Tanger Med Zones. https://www.tangermed-zones.com/en/zones/tanger-automotive-city/.

Thompson, D. 2025. "Africa's Quantum Leap." *Nature,* May 6. https://www.nature.com/articles/d44148-025-00129-x.

Trading Economics. 2026. *Morocco Exports of Electrical Energy to Spain—2026 Data 2027 Forecast 2002–2024 Historical.* Trading Economics. https://tradingeconomics.com/morocco/exports/spain/electrical-energy.

TRT Afrika. 2025. "Africa's Green Hydrogen to Create Millions of Jobs by 2050: Ramaphosa." June 12. https://trt.global/afrika-english/article/9f1ebe301900.

United Nations. 2018. *World Economic and Social Survey 2018.* United Nations, New York. https://policy.desa.un.org/sites/default/files/inline-images/eapd2023/WESS2018_ch1_en.pdf.

UNCTAD (United Nations Conference on Trade and Development). 2022. "Morocco—Adopts a New Investment Charter." *Investment Policy Monitor.* https://investmentpolicy.unctad.org/investment-policy-monitor/measures/4186/adopts-a-new-investment-charter.

UNCTAD (United Nations Conference on Trade and Development). 2023 Global Report on Blockchain and Its Implications on Trade Facilitation Performance. https://unctad.org/system/files/official-document/tcsdtlinf2023d1_en.pdf

UNCTAD (United Nations Conference on Trade and Development). 2025. *Technology and Innovation Report 2025: Inclusive Artificial Intelligence for Development.* United Nations, Geneva. https://unctad.org/system/files/official-document/tir2025_en.pdf.

UNDESA (United Nations Department of Economic and Social Affairs). 2024. *UN E-Government Survey 2024.* United Nations, New York. https://publicadministration.un.org/egovkb.

UNDP (United Nations Development Programme) Regional Bureau for Africa. 2024. *Africa Development Insights: Artificial Intelligence for Development (Q2 2024).* UNDP, New York. https://www.undp.org/sites/g/files/zskgke326/files/2024-07/undp_africa_africa_devt_insights-_ai_q2-2024_0.pdf.

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2024. "International Year of Quantum Science and Technology." July 7. https://www.unesco.org/en/years/quantum-science-technology.

Verified Market Research. 2025. *Africa Pharmaceutical & Biotechnology Market Size & Forecast.* Verified Market Research. https://www.verifiedmarketresearch.com/product/africa-pharmaceutical-biotechnology-market/.

WEF (World Economic Forum). 2025. *Artificial Intelligence for Efficiency, Sustainability and Inclusivity in TradeTech.* World Economic Forum, Geneva. https://reports.weforum.org/docs/WEF_Artificial_Intelligence_for_Efficiency_Sustainability_and_Inclusivity_in_TradeTech_2025.pdf.

WHO (World Health Organization). 2022. "Reflecting on the Implementation of Genomic Surveillance for COVID-19 and Beyond in the African Region." https://www.who.int/news/item/16-09-2022-reflecting-on-the-implementation-of-genomic-surveillance-for-COVID-19-and-beyond-in-the-african-region.

WHO (World Health Organization) Regional Office for Africa. 2022. "A Day in the Life of Kenya's COVID-19 Genomic Sequencing Team." https://www.afro.who.int/photo-story/day-life-kenyas-covid-19-genomic-sequencing-team.

Wilson, O. 2025. "Top 8 Biotech Startups Creating Waves in Africa in 2025." *Scispot,* May 31. https://www.scispot.com/blog/biotech-startups-creating-waves-in-africa.

WIPO (World Intellectual Property Organization). 2022. *Frontier Technologies – 6th Factsheet.* WIPO, Geneva. https://www.wipo.int/documents/d/frontier-technologies/docs-en-pdf-frontier-tech-6th-factsheet.pdf.

WIPO (World Intellectual Property Organization). 2025. "Measuring Genome Sequencing Costs and Its Health Impact." March 19. https://www.wipo.int/en/web/global-health/w/news/2025/measuring-genome-sequencing-costs-and-its-health-impact.

World Bank. 2014. *South Africa's Renewable Energy IPP Procurement Program.* World Bank, Washington, DC. https://openknowledge.worldbank.org/entities/publication/141693cf-1ed8-587d-9f30-0a7ef30c4998.

World Bank. 2022. *Toward Efficient, Sustainable and Safe Urban Transport in Madagascar.* World Bank, Washington, DC. https://documents1.worldbank.org/curated/en/099501504142221115/pdf/IDU0a975cced077a1045e-208b6a028cf0839ec7d.pdf.

World Bank. 2023. *Digital Progress and Trends Report 2023.* World Bank, Washington, DC. https://documents1.worldbank.org/curated/en/099031924192524293/pdf/P180107173682d0431bf651fded74199f10.pdf.

World Bank. 2025. "Africa's Higher Education Centers of Excellence: Celebrating a Decade of Transformative Journey in Revolutionizing Africa's Contribution to Global Research and Innovation." World Bank, April 7. https://www.worldbank.org/en/news/press-release/2025/04/07/africa-higher-education-centers-of-excellence-africa-contribution-to-global-research-and-innovation.

World Population Review. 2025. *Antananarivo Population 2026.* World Population Review. https://worldpopulationreview.com/cities/madagascar/antananarivo.

Zaatari, R. 2022. *The Green Economy of Morocco.* PhD diss., University of Glasgow. https://theses.gla.ac.uk/83070/1/2022zaatariphd.pdf.

END NOTES

1 UN 2018.
2 WIPO 2022.
3 African Union 2020.
4 World Bank 2023.
5 WEF 2025.
6 UNCTAD 2025.
7 African Union 2024.
8 Gilbert 2025.
9 Spurt 2024.
10 UNDP Regional Bureau for Africa 2024.
11 PwC 2017.
12 Matimba 2025.
13 6Wresearch 2023.
14 GSMA Intelligence 2024.
15 PwC 2020.
16 Coetzee and Stoffberg 2024.
17 Coetzee and Stoffberg 2024.
18 Coetzee and Stoffberg 2024.
19 UNCTAD 2023
20 Chainalysis 2023.
21 UNCTAD 2025.
22 Grand View Research 2025.
23 Verified Market Research 2025.
24 Wilson 2025.
25 Precedence Research 2025.
26 WIPO 2025.
27 Mobility Foresights Pvt Ltd 2025.
28 Africa CDC 2023.
29 Ochola 2025.
30 Africa CDC 2023.
31 WHO Africa 2022.
32 WHO 2022.
33 Buckholtz 2020.
34 Rodrigue 2024.
35 Abraham et al. 2021
36 IEA 2024b.
37 IEA 2025a.
38 Nkosi 2025.
39 Siemens 2025.
40 ECA 2026.
41 ECA 2026.
42 ECA 2022.
43 IRENA and AfDB 2022.
44 IEA 2024a.
45 BloombergNEF 2024.
46 Global Solar Council 2025.
47 IEA 2014.
48 Global Wind Energy Council 2025.
49 Blewett 2025.
50 Adeyeye et al. 2021.
51 IRENA 2024.
52 IEA 2025b.
53 UNCTAD 2025.
54 IOA 2025.
55 Labuschagne 2025.
56 TRT Afrika 2025.
57 Thompson 2025.
58 UNESCO 2024.
59 Iderawumi 2025.
60 Market Data Forecast 2025.
61 Mordor Intelligence 2025.
62 El Zoghby 2019.
63 SciDev.Net Staff 2017.
64 Daily Trust 2022.
65 CSIR 2022.
66 FAO 2024.
67 Matchaya et al. 2025.
68 Eghosa 2025.
69 Denebola Technologies 2024.
70 Distor et al. 2023.
71 Raithatha and Storchi 2025.
72 FSD Kenya 2019.
73 Laabi 2017.
74 El Hafdaoui et al. 2025.
75 Mahia & De Arce 2020; Zaatari 2022.
76 Trading Economics 2026.
77 Smith 2023.
78 World Bank 2014.
79 Siyobi 2023.
80 World Bank 2014.
81 Ntuli and Helgenberger 2019.
82 World Bank 2014.
83 Baker et al. 2015.
84 Leung et al. 2024.
85 Government of the Republic of Namibia 2022.
86 Leung et al. 2024.
87 Leung et al. 2024.
88 Boubker et al. 2024.
89 Leung et al. 2024.
90 Nkosi 2025
91 North Africa Post 2025.
92 IEA 2017.
93 UNCTAD Investment Policy Hub 2022.
94 Nkosi 2025.
95 World Bank 2025.
96 Tier 1 suppliers are the suppliers that a company directly contracts with. Tier 2 suppliers are direct suppliers to Tier 1 suppliers. Tier 3 suppliers provide resources to the Tier 2 suppliers.
97 Tanger Med 2026.
98 World Population Review 2025.
99 World Population Review 2025.
100 World Bank 2022.
101 Razafimanantsoa and Africanews 2024

CHAPTER 4 DATA: THE NEW OIL FUELLING FRONTIER TECHNOLOGIES

DATA, STATISTICS, AND ECONOMIC TRANSFORMATION IN AFRICA

The African Union's Digital Transformation Strategy identifies data as one of the key issues underpinning Africa's economic transformation (chapter 3). Data inform evidence-based governance, policy and strategy design, and development. But measures such as the frontier technology readiness index—which aggregates components measured with varying precision, uses normative weighting options, and combines indicators of readiness with those reflecting actual use (chapter 2)—demonstrate the challenges of using data in economic analysis to inform policy.

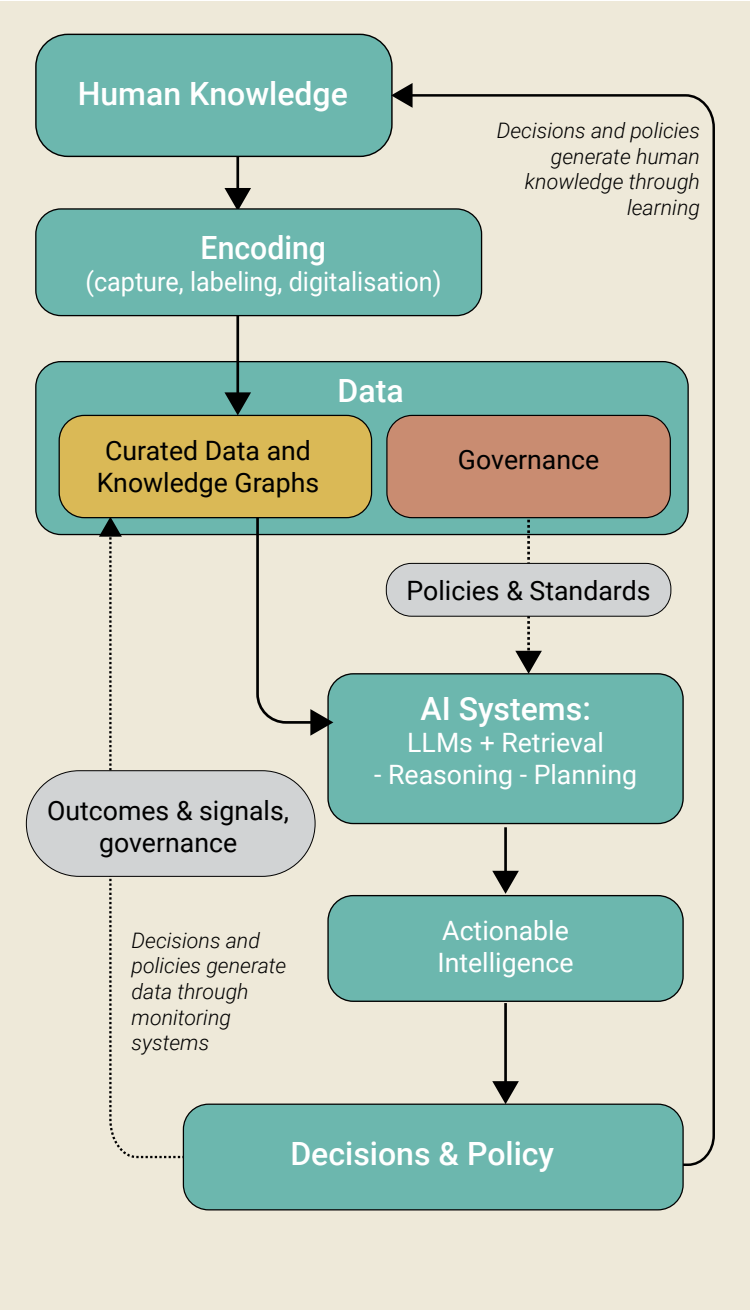
Data, including statistics,[1] are increasingly recognized as both a response to and a lever for Africa's economic challenges, serving as a diagnostic tool to understand problems and a strategic asset to drive solutions for transformation. Data hold a strategic economic asset role underpinning new value creation, productivity growth, and competitiveness in digital markets across finance, agriculture, health, logistics, energy, and the like. But data gaps inhibit translating economic growth into transformation of livelihoods and the structure of economies.[2] This is because of the weak connections between data and policy design. Economic growth volatility is either a cause or a consequence of poor, vulnerable, or uncertain investment and saving decisions by governments, firms, and households—decisions underpinned by data and the gaps therein. Traditionally, the reasons behind data gaps have been broadly divided into two categories: capacity (human and financial) and enabling environment (governance, systems, and trust). While African countries continue to grapple with these traditional challenges, the rapid evolution of technology has emerged as either an opportunity for or a threat to addressing or exacerbating existing constraints.

The emergence of both opportunities and threats is due to the dual nature of data, as both an input and an output, as well as to data characterizations and the continuous increase in data volume. In particular, frontier technologies showcase the worth and risk exposure of technology-related data to the statistics and policy community, which includes government, private investors, and the data subjects (consumers and producers). On data as an input, companies driving frontier technologies have fed their systems through diverse platforms for knowledge generation, which has enhanced technical, cost, time, and operational efficiencies. These gains constitute one of the discourse dimensions on the contemporary value of data relative to the traditional viewpoint.

On data as an output, frontier technologies have created large volumes of data with high speed, yielding an unprecedented scale and scope of data availability for analytics and policy insights. Data analytics and policy insights have also benefited from the resourcefulness of frontier technologies through deeper insights and integration of varied and new data sources and platforms for distilling and sharing statistical outputs. Despite the exponential growth in data generation and analysis and dissemination, uptake of evidence-based policies in Africa remains limited. Many African countries still rely on legacy systems and fragmented formats, making it difficult to convert data into actionable insights.

The foregoing underscores the motivation behind the search for the value of data in this digital era given the diverse ingenuity for innovation, economic competitiveness, resilience, and national security and overall economic growth and development. This is because harnessing data and frontier technologies through innovation holds the potential to drive meaningful economic progress and development. But there are risk exposures, including potential compromises of data privacy and security, external data control, data sovereignty, and non-adherence to professional standards for official statistics–based policymaking. In a data-driven world, no data or poor-quality data on a population subgroup also means that subgroup is left behind by the many algorithms trained on data that score us and run or will soon run many aspects of our lives (credit score, social score, facial recognition, and the like). Data and decisionmaking support each other in a virtuous loop that determines competitiveness (figure 4.1). Lacking good-quality data means not benefiting from that virtuous cycle and not being competitive in a data-driven world.

Figure 4.1 The new data generation cycle: The example of artificial intelligence



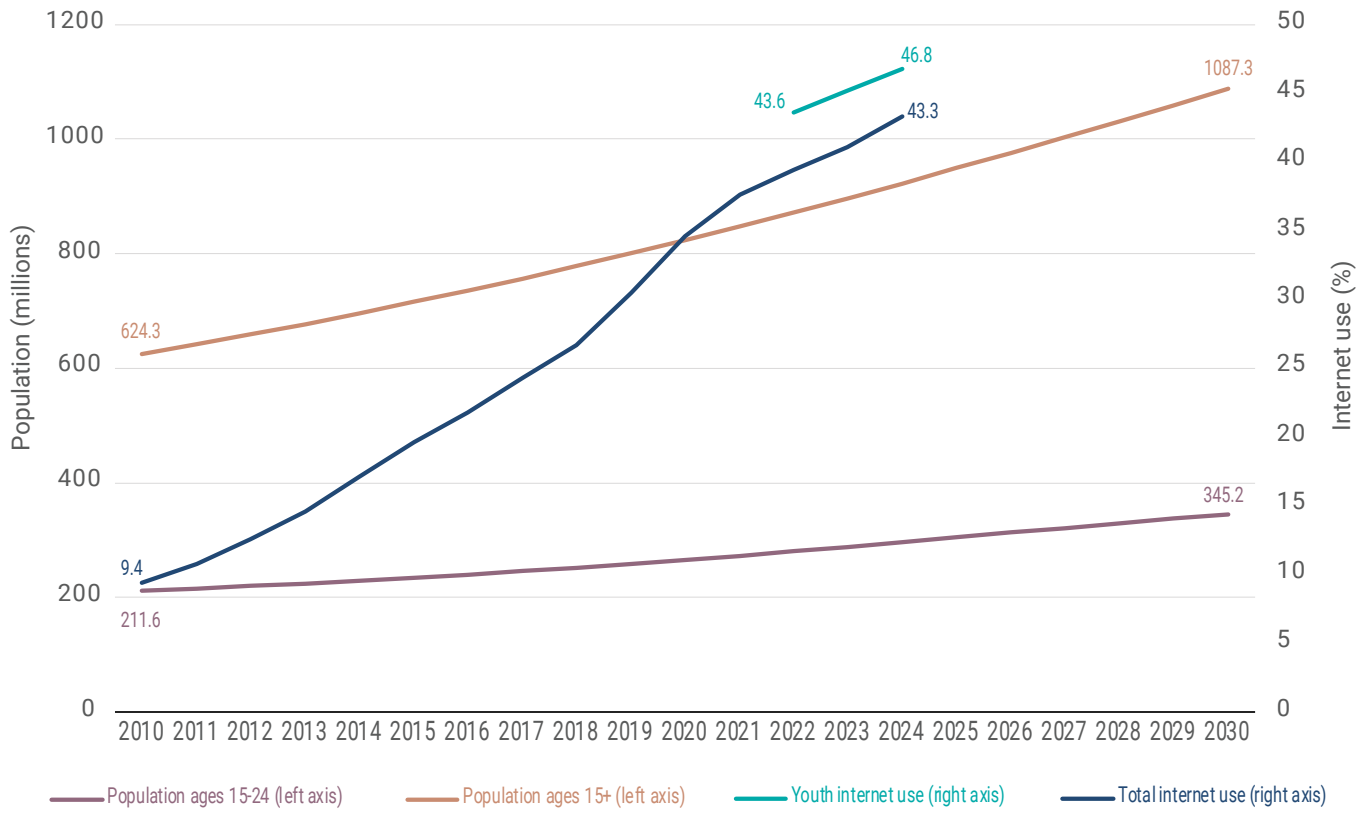
Source: ECA.

DATA VALUE CHAINS: THE SIGNIFICANCE OF DATA FOR AFRICAN ECONOMIES

The metaphor "data is the new oil," first coined by UK data scientist Clive Humby in 2006,[3] captures the essence of the digital economy's transformation: raw data, like crude oil, must be mobilized and refined through various stages, infrastructure, analytics, and algorithms to unlock its value. In the 21st century, frontier technologies—such as artificial intelligence (AI), blockchain, Internet of Things (IoT), and quantum computing (chapter 3)—have emerged as engines of economic growth, each powered by vast volumes of continuously generated data. But in Africa, limited access to high-performance computing and reliable energy infrastructure constrains the ability of many institutions to move beyond descriptive analytics towards advanced machine learning and AI applications.

For African economies, this paradigm shift presents a dual challenge: the need to avoid digital dependency while leveraging data to leapfrog traditional development pathways. With a youthful population, expanding mobile penetration, and growing innovation ecosystems, Africa is poised to harness the data revolution (figure 4.2). But without strategic investment in infrastructure, governance, and skills, the continent risks remaining a passive consumer in the global data economy.

Figure 4.2 Youth population and internet use in Africa, 2010–2030



Note: Data for 2026–2030 are projections.
Source: ECA, compiled from UN World Population Prospects (for population series), SDG (for Total internet use), and ITU (for Youth internet use) databases.

As of 2025, 39 of 55 African Union members had enacted data protection laws, and 34 had established data protection authorities to oversee compliance and enforcement.

In the digital age, data have become a foundational resource for economic competitiveness, national security, and innovation. Data-driven technologies were projected to contribute more than $100 trillion to the global economy by 2025.[4] Unlike oil, data are non-rivalrous and infinitely replicable, gaining value through aggregation and analysis.[5] But reaping data benefits does not happen without risk of prejudice to personal data. Countries have responded by crafting national data strategies. For instance, the European Union's General Data Protection Regulation sets global standards for data privacy and sovereignty, China's Cybersecurity Law and Data Security Law assert control over domestic data flows; and the United States relies on sectoral regulations and market-driven innovation. In Africa, the African Union Commission's *Digital Transformation Strategy for Africa (2020–2030)* recognizes the foundational role of enabling environments, policies, and regulations. Consequently, the Malabo Convention on Cyber Security and Personal Data Protection, which aims to harmonize data governance across borders and to support digital trade, entered its implementation phase in June 2023. As of 2025, 39 of 55 African Union members had enacted data protection laws, and 34 had established data protection authorities to oversee compliance and enforcement. Despite ongoing efforts such as the AU data policy framework,[6] challenges persist regarding fragmented regulations, limited resources, and concerns over data sovereignty, especially without connected systems and harmonized digital trade rules, and over foreign control of infrastructure.

DATA VALUE CHAINS: FROM DATA GENERATION TO ECONOMIC IMPACT

In the data economy, data are treated as a valuable asset, as organizations collect and analyse data from internal systems, customer interactions, market research, social media, and the like to gain a competitive edge. In the contemporary global economy, data have emerged as a foundational asset that rivals traditional factors of production such as land, labour, and capital. The metaphor "data is the new oil" has gained traction not merely for its rhetorical appeal but also because it captures the transformative potential of data when refined, structured, and strategically deployed. But unlike oil, data are non-rivalrous, infinitely replicable, and capable of generating increasing returns when aggregated and analysed. Nevertheless, frontier technologies trained on recursively generated data without quality human input may lead to catastrophic outcomes, stressing the importance of quality and governance.[7] Also, data's value is not intrinsic but contextual, derived from the ability to inform decisions, automate processes, and generate predictive insights across sectors when aggregated.

The economic value of data unfolds through a multistage process, beginning with its generation (figure 4.3). Data are continuously produced through digital interactions, transactions, sensors, mobile devices, and enterprise systems. In Africa, the proliferation of mobile phones and the increasing penetration of mobile internet have created vast streams of behavioural and transactional data, which—if harnessed effectively—can inform financial inclusion strategies, public health interventions, and agricultural optimization. Data generation is increasingly ubiquitous, with an estimated 120 zettabytes of data created globally in 2025, up from 64.2 zettabytes in 2020.[8]

Figure 4.3 The stages of data value chains

Source: ECA.

Once generated, data must be stored securely and efficiently. This involves databases, cloud platforms, and distributed ledger technologies. The rise of hyperscale data centres in Europe, North America, and parts of Asia reflects the strategic importance of data storage infrastructure. Digital Earth Africa stores petabyte-scale satellite and derived datasets in an open data cube hosted on Amazon Web Services in Cape Town, ensuring long-term, cloud-based access. But data storage remains a critical bottleneck in Africa, with only a handful of Tier III data centres across the continent.[9] The lack of localized storage facilities on the continent has implications for data sovereignty, latency, and regulatory compliance, particularly in healthcare and finance, where data sensitivity is paramount.

The third stage, processing, entails the cleaning, structuring, and transformation of raw data into usable formats. This is a prerequisite for interoperability and for feeding data into analytical engines. Processing is often

In Africa, the proliferation of mobile phones and the increasing penetration of mobile internet have created vast streams of behavioural and transactional data, which—if harnessed effectively—can inform financial inclusion strategies, public health interventions, and agricultural optimization.

overlooked in policy discourse, yet it is essential for ensuring data quality, reducing bias, and enabling meaningful insights. With frontier technologies such as machine learning and AI, preprocessing data determines the accuracy and fairness of algorithmic outputs. For example, biased or incomplete datasets can lead to discriminatory outcomes in credit scoring or recruitment algorithms, exacerbating existing inequalities. AI is also fuelling the growth of low-paid "crowdwork" (such as data labelling and annotation), much of which is outsourced to developing countries, raising serious concerns about compliance with the principles of decent work.[10]

After processing is the analysis phase, where statistical models, machine learning algorithms, and visualization tools are applied to extract patterns, correlations, and forecasts. This stage is where data begin to generate tangible economic value. In agriculture, predictive analytics can inform planting schedules and pest control strategies; in urban planning, geospatial data help optimize traffic flows and infrastructure deployment; and in public health, epidemiological models can anticipate disease outbreaks and allocate resources accordingly. The analytical capacity of a country or organization is thus a key determinant in its ability to convert data into actionable intelligence.

In the final stage, monetization, data are directly sold, licensed, or used to create value-added services. Monetizing data has given rise to a burgeoning global data economy, with the European Commission estimating the value of the EU data market at €829 billion in 2022 and projecting it to exceed €1 trillion by 2025. In the United States, digital (mainly data-driven) advertising alone accounted for more than $200 billion in revenue in 2023.[11] These figures underscore the centrality of data in contemporary business models, particularly in e-commerce, financial technology, and digital media.

Value is not evenly distributed across the five stages of Africa's data value chain. African economies participate mainly in upstream data generation and low-value storage, while the downstream stages of processing, analysis and monetization—which generate the highest economic rents, learning-by-doing, and intellectual property—are performed in foreign data centres and cloud environments. The continent thus effectively exports a strategic input (user and transaction data) and imports high-margin finished intelligence and digital services. This pattern reinforces structural dependence; shifts profits, high-skill jobs, and technological capabilities offshore; and worsens the balance of payments through recurrent payments for cloud, software subscriptions, and AI services. Without clear continental and national rules on data governance (including conditions for cross-border transfers, responsibilities of firms handling African data, and calibrated localization or local processing requirements for strategically important data), the data economy risks reproducing an extractive model. Africa would again supply the raw material (behavioural, financial, health, geospatial, and other user data) and perform low-value processing while foreign actors capture most of the value at the more advanced stages of processing, analysis, and monetization.

Without clear continental and national rules on data governance (including conditions for cross-border transfers, responsibilities of firms handling African data, and calibrated localization or local processing requirements for strategically important data), the data economy risks reproducing an extractive model.

VALUATION OF DATA MARKETS: TRENDS, SEGMENTS, AND GLOBAL ESTIMATES

The 2025 System of National Accounts (SNA) recognizes data as a foundational asset in the digital economy, underpinning production, innovation, and value creation across all sectors. Unlike traditional inputs, data can be reused and repurposed at zero to low marginal cost, enabling increased returns when combined with digital technologies. As the 2025 SNA emphasizes, data play a dual role as both an intermediate input and a form of capital, shaping productivity, business models, and competitiveness. Properly measuring and integrating data into economic accounts are therefore critical to capturing the full scope of digital transformation, ensuring comparability across countries, and informing policies that maximize data benefits while addressing risks related to governance, equity, and sustainability.

Intangible assets, including data, now account for more than 90 per cent of the market value of S&P 500 companies, up from just 17 per cent in 1975.[12] This shift reflects the growing importance of data-driven business models, where value is derived not from physical goods but from information flows, algorithms, and user engagement. In economic modelling, data behave differently from traditional capital by exhibiting increasing returns to scale, as large firms generate or capture more data, which improves their products and attracts more users. Data also demonstrate decreasing marginal utility, where predictive power often plateaus after a certain volume. Moreover, data depreciate over time, especially in fast-moving markets, as outdated information loses relevance and utility. The rise of data markets has institutionalized data's economic

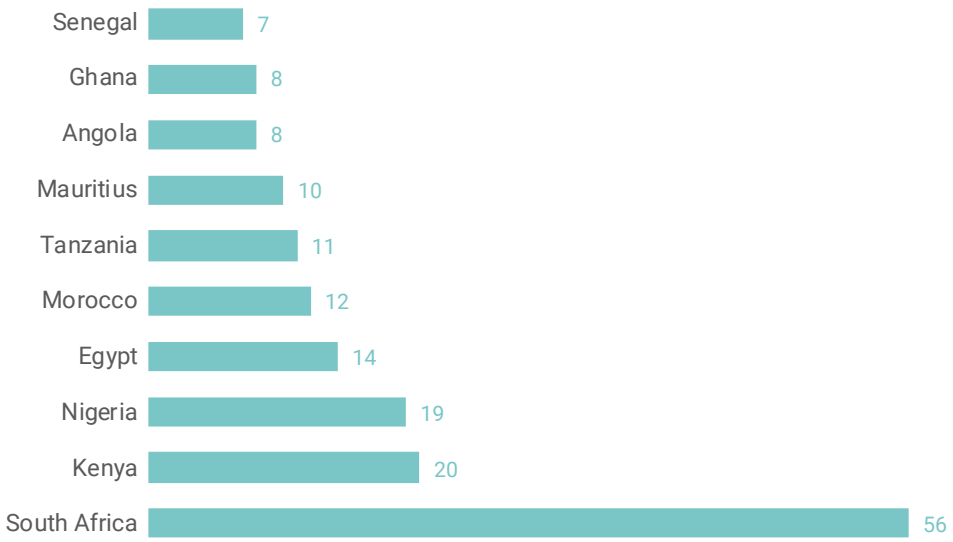
Intangible assets, including data, now account for more than 90 per cent of the market value of S&P 500 companies, up from just 17 per cent in 1975.73 This shift reflects the growing importance of data-driven business models, where value is derived not from physical goods but from information flows, algorithms, and user engagement.

role. These markets function as platforms where data are exchanged, aggregated, and priced. They include data-as-a-service providers, open data portals, and proprietary exchanges such as AWS Data Exchange and Snowflake Marketplace. Data markets are evolving rapidly, driven by demand for real-time insights, personalization, and automation.

Data market segmentation occurs along several dimensions. First, by data type: personal data, transactional data, geospatial data, sensor data, and health data, each serving distinct purposes and commanding different valuations. Second, by source: public sector data, private enterprise data, and user-generated data, each with varying accessibility and reliability. Third, by use case: marketing, risk modelling, supply chain optimization, urban planning, and scientific research, each requiring specific data attributes and formats.

Valuation within these markets is highly contextual. Personal data, often used for targeted advertising, command high prices due to granularity and behavioural insights. Financial data are valued for predictive power in credit scoring and fraud detection. Health data, particularly genomic and clinical datasets, are among the most valuable due to utility in drug discovery and personalized medicine. The global data monetization market is projected to grow from $4 billion in 2023 to more than $40 billion by 2034, with a compound annual growth rate of 25 per cent.[13] The global data analytics market generated revenue of $69.5 billion in 2024 and is expected to reach $302 billion by 2030. With 230 data centres as of August 2025, up from just 120 in October 2024, Africa accounts for less than 2 per cent of global capacity (see figure 4.4 for the distribution of data centres in the 10 African countries hosting the most data centres). It recorded $3.49 billion in investment in 2024, with $6.8 billion projected in 2030.

Figure 4.4 Ten African countries hosting the most data centres, August 2025



Source: Data Center Map (https://www.datacentermap.com).

Despite this growth, several challenges persist. Pricing mechanisms remain opaque, with limited standardization across platforms. Data provenance and quality assurance are often difficult to verify, raising concerns about reliability and ethical use. The commodification of personal data has sparked debates about privacy, consent, and digital rights. Scholars have critiqued the rise of "surveillance capitalism," wherein user data are extracted and monetized without adequate transparency or accountability.[14] Major data collecting companies in African are not African, meaning that Africa may be giving high-value data for free to companies outside the continent. Beyond the data sovereignty risk, foreign companies may use these data to outcompete African companies.

Although Africa-owned data centres are an initial step in making the data economy benefit African countries, expanding Africa's data centre footprint cannot be treated in isolation from the continent's energy challenges. Data centres are electricity-intensive infrastructure whose competitiveness and reliability depend on stable, affordable power and resilient grids. In countries where firms and households already face frequent outages and high tariffs, uncoordinated promotion of data centres risks exacerbating existing energy deficits or driving operators to rely on expensive, carbon-intensive backup generation. Instead, the data centre agenda must be explicitly integrated into national and regional power sector planning, including investment in transmission, flexible baseload, and renewables, in line with Africa's climate and industrialization goals.

Although Africa-owned data centres are an initial step in making the data economy benefit African countries, expanding Africa's data centre footprint cannot be treated in isolation from the continent's energy challenges.

THE VALUE OF DATA AND STATISTICS FOR DRIVING SUSTAINABLE AND INCLUSIVE DEVELOPMENT

Data and official statistics are foundational to informed economic governance, as they enable evidence-based decisions that are transparent, accountable, and responsive to citizen needs. Official statistics guide resource allocation, policy design, service delivery, and monitoring of national and global development objectives. Data and statistics' role is particularly critical for addressing economic shocks, reducing inequalities, and ensuring that targeted policy interventions reach marginalized populations, thus promoting sustainable and inclusive growth. For instance, high-quality statistics offer granular insights into societal conditions, empowering governments and partners to act on timely and reliable evidence. Modern data governance frameworks ensure these insights are relevant, ethical, and efficiently shared. Effectively using robust data also supports sound


© Adobe Stock

fiscal policy, environmental management, and health and education service delivery and fosters public trust—all vital to improving people's welfare.

Investment in data and official statistics consistently yields high economic and societal returns. Every $1 invested in data and statistical systems offers up to $32 in benefits through improved policymaking, efficient public spending, and prevention of costly policy errors.[15] Government analytics and data initiatives have documented returns as high as 8:1, with additional gains in operational transparency and citizen trust.[16]

Governments, with their transformative role, should systematically invest in strengthening national statistical systems and building resilient, modern data infrastructure. Such investment underpins sustainable and inclusive growth, ensuring responsive, fair governance and maximizing the collective benefits for all.

Governments, with their transformative role, should systematically invest in strengthening national statistical systems and building resilient, modern data infrastructure. Such investment underpins sustainable and inclusive growth, ensuring responsive, fair governance and maximizing the collective benefits for all.

DATA VERSUS OIL: A NUANCED ANALOGY AND THE ADVANTAGES OF DATA FOR AFRICAN ECONOMIES

While the metaphor "data is the new oil" captures the economic centrality of data, it oversimplifies key differences. Oil is a finite, rivalrous resource that is consumed upon use, whereas data are renewable, non-rivalrous, and capable of being reused and recombined. Oil extraction is geographically concentrated and geopolitically sensitive; data generation is ubiquitous and can be democratized, though its control remains uneven.

Both resources require infrastructure: pipelines for oil, fibre optics and cloud storage for data. Both require refining: crude oil through distillation, raw data through analytics and machine learning. And both necessitate governance: oil through environmental regulation and trade agreements, data through privacy laws, cybersecurity protocols, and ethical standards.

However, scalability and versatility make data uniquely suited in the digital age. Data can be used simultaneously by multiple actors, integrated across sectors, and leveraged for both commercial and public interest purposes. This makes data not just a commodity but a strategic enabler of innovation, inclusion, and resilience.

The analogy to oil is instructive: just as oil catalysed industrialization, data fuel digital transformation. However, this concentration of data power raises concerns about monopolies, surveillance, and digital colonialism,74 especially in regions such as Africa, where local data infrastructure remains underdeveloped.

For African economies, the analogy serves as a call to action. Just as oil-rich countries invested in extraction, refining, and distribution infrastructure, data-rich countries must invest in digital infrastructure, analytical capacity, and governance frameworks. The goal is not merely to extract value from data but to build ecosystems where data serve development, equity, and sovereignty.

The global data landscape is dominated by tech giants such as Amazon, Google, Meta, Microsoft, and Tencent, which operate massive data centres, cloud platforms, and AI models that process billions of data points daily. Their market capitalization, each exceeding $1 trillion, reflects the monetization of data across advertising, logistics, healthcare, and finance.

Again, the analogy to oil is instructive: just as oil catalysed industrialization, data fuel digital transformation. However, this concentration of data power raises concerns about monopolies, surveillance, and digital colonialism,[17] especially in regions such as Africa, where local data infrastructure remains underdeveloped.

FOUNDATIONS OF A DATA-DRIVEN ECONOMY: LEVERAGING DATA AS A KEY ASSET FOR ADVANCING FRONTIER TECHNOLOGIES

After demonstrating the importance of data value chains—through data generation, capture, storage, processing, organization, analysis, and information generation—and exploring data markets, this section highlights data's crucial role in frontier technologies. It emphasizes how data enhance economic sectoral performance and drive ripple effects through technology value chains, impacting national, regional, and international economies.

Without data, frontier technologies cannot function effectively. These technologies rely on transforming data into actionable capabilities. Data are used in various ways across frontier technologies, including blockchain, IoT, robotics, AI and machine learning, advanced automation, biotechnology, and smart cities.

DATA AS "NEW OIL," FUELLING FRONTIER TECHNOLOGIES: THE TWO-WAY RELATIONSHIP BETWEEN DATA AND FRONTIER TECHNOLOGIES

Without data, frontier technologies cannot function effectively. These technologies rely on transforming data into actionable capabilities. Data are used in various ways across frontier technologies, including blockchain, IoT, robotics, AI and machine learning, advanced automation, biotechnology, and smart cities.

Blockchain. Blockchain is one of the main frontier technologies that liaise with data. It is a secure, shared database where real-time information is accessible to all participants in a network.[18] But unlike traditional databases that store data in tables, blockchain stores data in digitally linked blocks (digital containers that store data).[19] Blockchain is most often used as a digital ledger technology for organizing transaction data.[20] Thus, without data, blockchain cannot function.

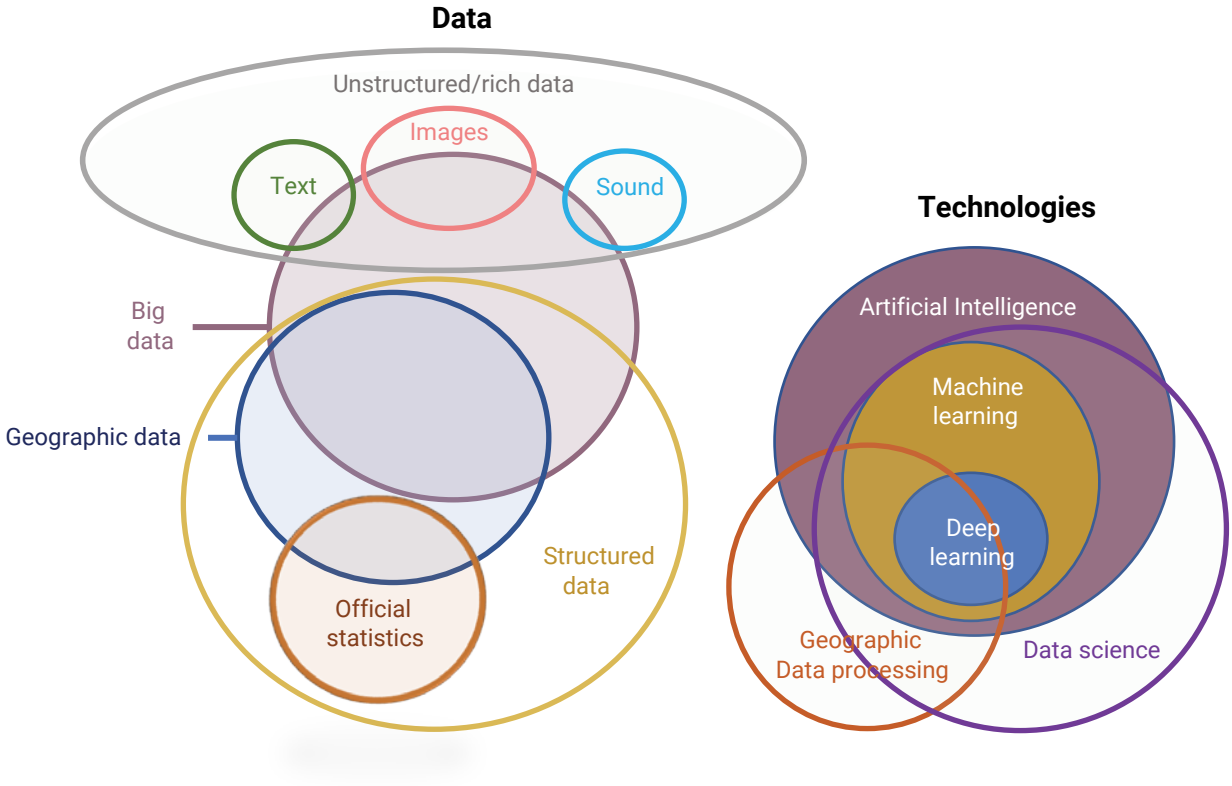
IoT. Blockchain has a key application in IoT.[21] The IoT enables digital interconnection across machines, industries, and supply chain partners, generating and exchanging large volumes of data, and blockchain secures these networks against attacks and data tampering. IoT can function as both a use case for and a complement to blockchain, and both depend heavily on data.[22] Combining IoT with data and analytics enables innovation and operational efficiency. Three data-focused criteria can be used to evaluate whether an IoT platform can meet organizational requirements: data management, integrating diverse datasets; cloud infrastructure ownership, ensuring data control; and edge processing,[23] enabling local analytics without cloud reliance.[24] Combining digitized machinery with IoT and data streams enhances supply chain efficiency.[25]

Robotics. While robotics has many applications, data remain essential, especially in emerging areas of these applications. Robotics technologies compare new data with stored information to determine the best course of action and generate data by integrating information technology with operational technology, enabling predictive maintenance and smoother operations.[26] Robotics also supports data science tasks such as data cleaning, automation, analytics, and anomaly detection. Furthermore, robotics is increasingly integrated with AI and machine learning. Although not all robots use AI, future advancements

in robotics will be closely tied to progress in AI, lower costs of mobile components, and innovations in materials and design.[27]

AI and machine learning. AI and machine learning are fundamentally data driven. They are not only applications within robotics that automate and organize data, but they are also closely linked to data science—terms often used interchangeably, despite key differences. While AI, machine learning, and data science are interconnected, they serve distinct purposes: Artificial intelligence relies on continuous data input to improve decisionmaking over time. Machine learning uses algorithms to learn from data and make predictions. Data science focuses on managing, processing, and interpreting large datasets to support decisionmaking.[28] AI increasingly depends on large and diverse data sources, known as "big data."[29] These datasets feed machine learning models, enabling them to learn and enhance performance without explicit programming. Despite their differences, the common thread among AI, machine learning, and data science is data.[30] Without data, none of these technologies can function. Figure 4.5 illustrates how AI, machine learning, and deep learning[31] in technology and data science are interconnected and build on one another. It also highlights different types of data, including structured data and unstructured data (also called rich data),[32] and how they are combined with big data to support advanced analytics, insights, and decisionmaking.

Figure 4.5 Types of data and technologies



Source: ECA.

Advanced automation. A key feature of AI, machine learning, blockchain, IoT, and robotics is their ability to automate tasks. Advanced automation integrates these and other technologies to deliver intelligent, adaptive, and efficient systems.[33] Like other frontier technologies, advanced automation depends on data, using data as an input and generating data as an output. For instance, it enables real-time data processing at the network edge, maintains data integrity and system reliability, and incorporates communication protocols and network architecture for seamless data exchange.[34]

Biotechnology. Biotechnology, combining biology and technology to improve quality of life, intersects with data through gold biotechnology, which analyses biological data, and purple biotechnology, which focuses on data protection.[35] Biotechnology also integrates with data science in biotechnology data analysis and analytics.[36]

Smart cities. Smart cities integrate frontier technologies with urban areas. Smart cities use IoT devices, software solutions, communication networks, and other technologies such as application programming interfaces, AI, cloud computing, dashboards, machine learning, machine-to-machine communication, mesh networks, and digital twins.[37] Mesh networks link devices to multiple nearby devices, allowing data to be passed along alternate paths so the network continues to function even if one device fails. Digital twins are virtual models of physical systems that use real-time data to track performance, test scenarios, and anticipate potential problems before they occur. Like other technologies, smart cities rely heavily on data. For example, they use surveillance and sensor data to optimize traffic, energy use, public safety, and city services in real time, making urban living more efficient and responsive and enhancing citizens' quality of life.[38] This approach highlights the need for strong data governance and cybersecurity frameworks to safeguard privacy, prevent misuse, and maintain public trust, since smart cities also face risks such as excessive surveillance, data breaches, digital inequality, and dependence on complex technologies that may fail or be exploited.

Table 4.1 summarizes the interaction between frontier technologies and data, showing data as input (raw material) and output for frontier technologies. The next subsection explores the importance of data from frontier technologies in performance across economic sectors.

Table 4.1 Summary of the interactions between frontier technologies and data

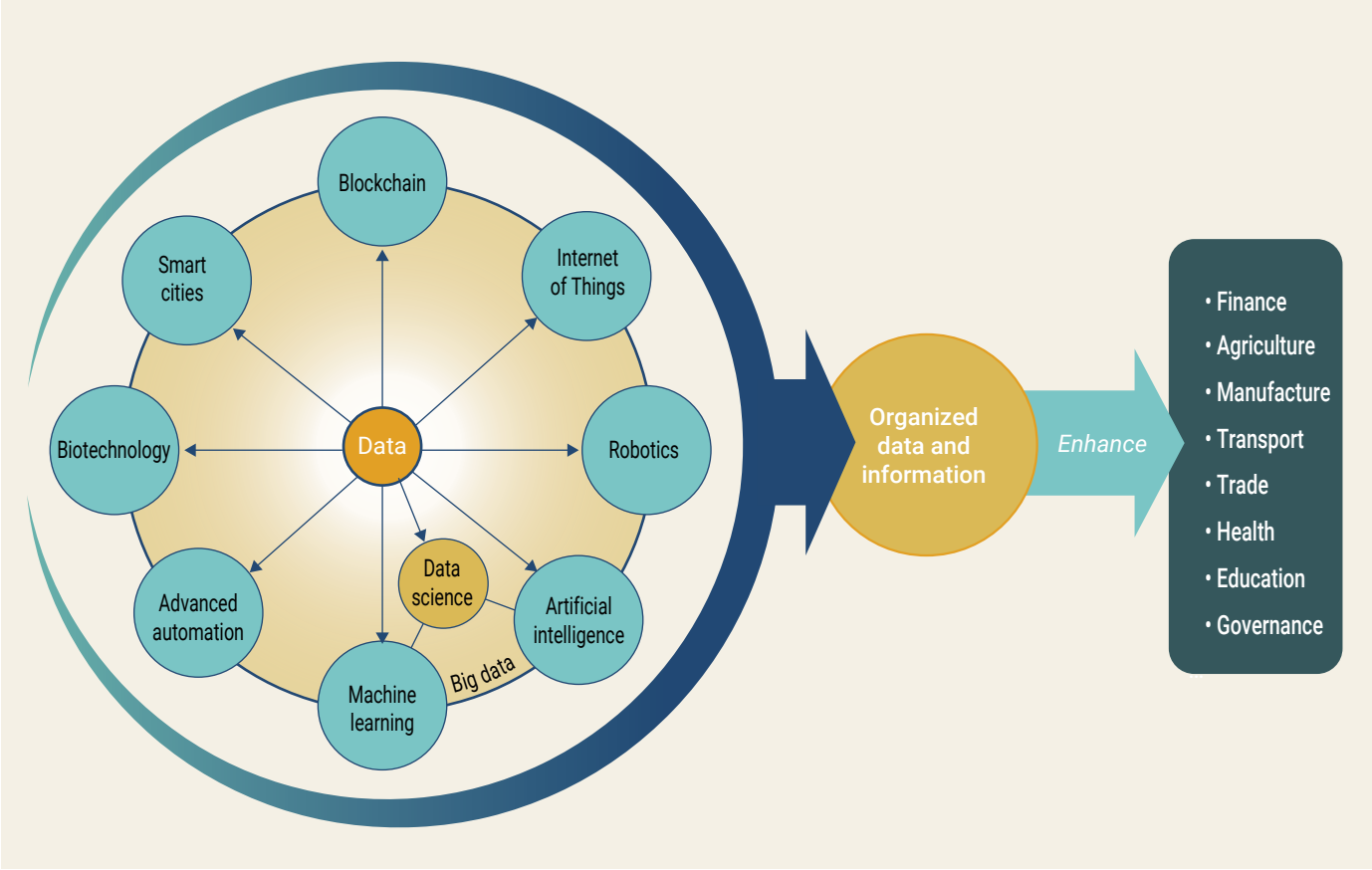
Frontier technology	Data as input	Data as output
Blockchain	Uses data to validate, record, and secure transactions in an immutable and decentralized ledger.	Transaction data, secure data, block metadata, and audit trails, which record immutable details of digital exchanges.
Internet of Things	Uses data collected from interconnected devices to monitor conditions, trigger responses, optimize device interactions, and enable real-time decisionmaking.	Real-time data and sensor readings, device telemetry, usage statistics, and event alerts from interconnected devices.
Robotics	Uses data from sensors, cameras, and control systems to perceive environments, detect objects, perform complex tasks, control movements, make decisions, and execute precise physical actions.	Sensor data, movement logs, task completion reports, and environmental interaction data.
Artificial intelligence	Uses data from large volumes to train models, simulate human intelligence, detect patterns, make predictions, and make intelligent decisions, all while adapting over time.	Inference data, organized and classified data predictions, anomaly detections, and recommendation scores, based on processed input data.
Machine learning	Uses historical data, real-time data, structured data, and unstructured data to train models and algorithms, optimize performance, generate predictions, and automate insights over time.	Model predictions, classification labels, confidence scores, and training metrics.
Biotechnology	Uses biological data, such as genetic, cellular, or molecular information, to analyse biological systems and develop medical, agricultural, bioengineering, and genetic solutions.	Genomic sequences, biological assay data, lab experiment results, clinical outcome data.
Advanced automation	Uses data from sensors, machines, processes, systems, and user inputs to perform repetitive and complex tasks with minimal human intervention and high efficiency.	Process execution data, task execution data, error logs, efficiency metrics, and system status updates from automated tasks.
Smart cities	Collects, uses, and analyses integrated data from transportation, energy, public services, citizens, and the environment to manage infrastructure; improve urban services, operations, planning, sustainability, and quality of life; and enhance decisionmaking.	Urban sensor data, integrated urban data, traffic flow information, energy use statistics, air quality indices, environmental conditions, public safety alerts, and citizen feedback logs.

Source: ECA.

HOW DATA FROM FRONTIER TECHNOLOGIES ENHANCE ECONOMIC AND SOCIAL SECTOR PERFORMANCE

This subsection shifts the focus to data, particularly the data generated through frontier technologies. It explores how these data can be leveraged to improve performance in finance, agriculture, manufacturing, transport, trade, health, education, and governance (figure 4.6).[39] Across all these sectors, data play a vital role in guiding decisions, from initial project planning to ongoing monitoring, adjustments, and final evaluations.

Figure 4.6 The data-driven economy through frontier technologies



Source: ECA.

Across all sectors, data play a vital role in guiding decisions, from initial project planning to ongoing monitoring, adjustments, and final evaluations.

Finance. Finance stands out among the sectors most positively influenced by data from frontier technologies, especially blockchain, IoT, and AI. These technologies generate data that play a critical role in transforming financial services. The growing availability of data in finance has driven the adoption of AI techniques, reshaping how the sector operates.[40] Data support all actors in the financial value chain, from institutions that provide financial services to individuals, businesses, and governments that use them. For financial institutions, access to real-time, high-quality data enables broader outreach, especially through financial technology solutions and mobile banking platforms. Data have allowed many African countries to achieve financial inclusion, through advanced digital finance. For

example, in 2024, the Central Bank of Rwanda further advanced digital finance by launching a pilot for a central bank digital currency, the Rwanda e-Franc. The initiative aims to promote financial inclusion, reduce transaction costs, and provide a secure, regulated alternative to private cryptocurrencies. The pilot is being tested through a closed user group involving selected financial institutions.[41] This not only expands access to financial services but also grows customer bases and drives increased revenue.

The benefits go beyond the providers. Individuals and businesses, especially micro, small, and medium enterprises, gain greater visibility and trust within the financial system. Using data-driven insights allows lenders and investors to more accurately evaluate creditworthiness, close information gaps, and develop financial products that are more inclusive and tailored to real needs. As a result, micro, small, and medium enterprises can access financing more easily and on better terms, enabling them to grow, innovate, manage cash flow more effectively, and maintain long-term sustainability. By using data to boost earnings, financial institutions also enhance their ability to make informed decisions, incorporating data analytics to spot trends, build forecasts, and solve complex financial modelling scenarios. AI-driven tools can assess borrowers' creditworthiness more efficiently, streamline underwriting, and optimize portfolio management.[42]

Risk management is another area where frontier technology data have a major impact. Financial institutions can detect fraud more effectively

Finance stands out among the sectors most positively influenced by data from frontier technologies, especially blockchain, IoT, and AI.

and assess potential risks with greater accuracy. For instance, a pyramid scheme disguised as a cryptocurrency investment defrauded hundreds of Rwandans through the Telegram and WhatsApp platforms. Thanks to data generated by frontier technologies, the Rwanda Investigation Bureau arrested key suspects and launched a nationwide public awareness campaign on digital scams.[43]

On the user side, access to risk-related data allows individuals and businesses to make better investment decisions and select loan products more confidently. Moreover, the data-driven expansion of financial services has broader implications. Increased access to financial products empowers consumers by offering more personalized services and unlocking deeper insights for investment. For clients with limited credit history, data analytics can open doors to credit through alternative credit scoring, thus enhancing financial inclusion. Governments also benefit from these advancements, since as financial activity grows, so does the tax base, allowing for higher public revenue. Technologies such as blockchain and automated monitoring systems also combat tax fraud and evasion, making financial systems more transparent and accountable.

Agriculture. Data, especially big data, play a transformative role in agriculture. Data not only increase farm income when used effectively but also streamline every stage of fieldwork, from selecting the right crops and preparing the soil to planting and harvesting. One of the most valuable contributions of data, processed through AI and machine learning, is the ability to forecast weather conditions, including rainfall. Accurate predictions are vital, as rainfall influences which crops can be cultivated during specific seasons. Equally important is understanding the soil itself; by analysing data, farmers can identify which crops are best suited to their land, maximizing yield and profitability.

Data, especially big data, play a transformative role in agriculture. Data not only increase farm income when used effectively but also streamline every stage of fieldwork, from selecting the right crops and preparing the soil to planting and harvesting.

AI-driven data insights also guide when, where, and how fertilizer should be applied, ensuring efficiency and reducing waste. In addition, drones used for irrigation help reduce reliance on unpredictable rain patterns. When combined with geospatial data, they can accurately target specific areas, improving water use and crop health. The data collected by AI-equipped drones, covering moisture levels, soil composition, and crop condition, are instrumental in boosting yields and minimizing waste, laying the groundwork for precision agriculture. Integrating IoT and AI also enables real-time monitoring of plant development, helping farmers adjust irrigation, solar energy use, and fertilizer application as needed. Agribusiness also has an important role in this ecosystem. With the right data, agribusinesses can enhance productivity and drive higher economic returns.

An African farmer in his field with a tablet in his hand, technology in agriculture in Africa..© Adobe Stock

Data are increasingly being used in agriculture for economic transformation in Africa. The United Republic of Tanzania and South Africa provide two examples.

"Agriculture remains the backbone of Tanzania's economy, and data innovations are transforming this sector. In 2024, the government launched the Data for Digital Agricultural Transformation program to leverage frontier technologies for farming. Under this initiative, digital platforms are being introduced to deliver real-time data to farmers—such as weather forecasts, pest outbreak alerts via mobile phones, and market price information through SMS services. Drones and satellite imaging are also being piloted to monitor crop conditions (for instance, assessing crop health or drought stress from aerial imagery). Early results show increased yields and resilience where these tools have been tested. Farmers receiving SMS price updates have been able to negotiate better and decide when and where to sell produce, improving their incomes. Remote sensing data has helped predict harvests and guide agricultural extension services to areas in need of support. In Dodoma and other pilot regions, smallholder farmers have reported improved decision-making, such as optimizing planting dates based on weather analytics. This use of data thus contributes to food security and economic empowerment in rural communities."[44]

South Africa is advancing smart agriculture in the Western Cape by leveraging data from three key frontier technologies: IoT sensors that monitor soil conditions and crop health, AI systems that predict weather trends and pest outbreaks, and drones and automation technologies that enhance efficiency and optimize farming operations.[45]

South Africa is advancing smart agriculture in the Western Cape by leveraging data from three key frontier technologies: IoT sensors that monitor soil conditions and crop health, AI systems that predict weather trends and pest outbreaks, and drones and automation technologies that enhance efficiency and optimize farming operations.

Manufacturing. Manufacturing enjoys advantages from data derived from frontier technologies. For instance, big data analytics and the growing value of data tracking are reshaping industries throughout the private sector, including among micro, small, and medium enterprises.[46] When combined with cutting-edge technologies such as machine-to-machine communication, IoT, cloud computing, cybersecurity tools, advanced robotics, AI, smart sensors, augmented and virtual reality, and three-dimensional printing, these innovations are transforming manufacturing in South Africa. The government there is developing an industrial strategy based on economically competitive technology platforms that address economic and social imperatives to improve competitiveness and prepare for the fourth industrial revolution.[47] As a result, South Africa now ranks among the world's 30 most diversified and integrated supply chains. It holds the leading position in Africa on both the frontier technology readiness index and the Logistics Performance Index.[48] The country also boasts one of the largest information and communications technology markets on the continent, with a particularly strong electronics sector. Beyond South Africa, data generated through robotics, AI, and machine learning have a critical role in driving innovation and efficiency across modern manufacturing systems.[49]

Transport. Data provided by frontier technologies such as blockchain, IoT, and AI are transforming how transport systems are managed. The data enable secure and efficient online booking systems, helping customers make informed choices based on their destination or transit points. Transport providers can also use the data to enhance services, streamline operations, and increase profitability, creating mutually beneficial partnerships across companies. Data from AI and machine learning also support predictive maintenance from sensors embedded in vehicles. Machine learning algorithms can process sensor data to anticipate maintenance needs, which is especially valuable in managing large fleets, such as those used in public transit systems.[50]

A notable illustration of data for transport in Africa is Shuttlers, a Nigerian transportation technology

startup that uses digital tools to improve commuting for professionals and organizations in busy cities such as Lagos.[51] Cofounded by a previous eTrade for Women advocate for English-speaking African countries, Shuttlers focuses on scheduled shared rides and data-enabled planning.[52]

Passenger and traffic flow management in airports, seaports, and bus and train stations is also made more efficient through data processed by AI and machine learning. Databases from blockchain and IoT ensure secure and tamper-proof data recording while providing real-time logistics tracking. mentioned In intelligent transportation Systems, data, robotics, and AI work together to optimize operations, enabling smart parking systems, route optimization, road safety improvements, flight route planning, passenger profiling, air traffic control, baggage handling, crew scheduling, fraud detection, and intelligent public transport systems.[53] Additionally, advanced GPS technologies supply vital real-time location data that support nearly every aspect of modern transportation.

Trade. The impact of frontier technology data is particularly strong in the growing field of e-commerce. Today, integrating data with frontier technologies has become essential for streamlining trade operations and enhancing efficiency. This includes faster delivery times, real-time shipment tracking, cost reduction, and increased revenue—the core elements of modern, data-driven commerce. Using data in trade has the potential to substantially accelerate regional economic integration, particularly in advancing the goals of the African Continental Free Trade Area (AfCFTA).

The Digital Transformation Strategy for Africa (2020–2030) and the AfCFTA Protocol on E-commerce, the AfCFTA provides a strong and coherent framework for managing data in the trade sector, particularly in digital trade.

As digital trade expands, it plays an increasingly important role in enhancing the effectiveness of the AfCFTA. And a stronger AfCFTA is essential for the growth of digital trade across Africa. Through such initiatives as the Digital Transformation Strategy for Africa (2020–2030) and the AfCFTA Protocol on E-commerce, the AfCFTA provides a strong and coherent framework for managing data in the trade sector, particularly in digital trade. Together, these initiatives, which are still under way, could create broad opportunities for the continent to harness

frontier technologies and data to advance digital trade, improve the quality African citizens' life, strengthen existing economic sectors, support diversification and development, and promote continental ownership. This approach could position Africa not only as a participant but also as a producer in the global digital economy.[54]

By combining data with IoT, businesses gain better visibility across their supply chains. In addition, data paired with blockchain technology support secure digital transactions, strengthening trading activities from the producer to the end consumer and adding value at every stage of the supply chain. Data combined with frontier technologies contribute to the diversification and interconnectivity of global supply chains.[55] In these dynamic systems, customers often become traders themselves, and vice versa. Blockchain could bring efficiency gains in several other trade areas, including cross-border clearance, stakeholder coordination, payment processing and trade finance, trade-risk management, trade data reporting and management, and traceability of value chains and transparency of supply chains, such as cargo integrity, corridor management, authorized economic operators, and rules of origin.[56]

Data combined with AI and machine learning can help address complex logistical and pricing challenges more efficiently, optimizing revenue while cutting down on operational costs and saving time. In addition, IoT-generated data support real-time tracking, enhance risk management, and help detect fraud. Blockchain databases further ensure transaction transparency and accountability, making digital trade not only faster but also more trustworthy. In 2020, Morocco's customs agency launched a blockchain-based project in cooperation with DHL and the German International Cooperation Agency to develop an ecosystem for sharing the data of parties to all international transactions (traders, express mail service, customs, and the like) in a secure manner among stakeholders for improved coordination and faster administration.[57] Thus, using data from frontier technologies positions digital trade as a core enabler of scale and competitiveness.

Health. The healthcare sector is experiencing major transformations thanks to data powered by frontier technologies, as data quality and trust are crucial for healthcare. It is one of the fastest-growing areas for such innovations. Blockchain databases have greatly improved pharmaceutical supply chains in several countries. Real Can (also known as Ruikang), a China-based pharmaceutical wholesaler, partnered with China Zheshang Bank to develop a blockchain-based supply chain financial system that has enabled faster, more reliable data processing, improved assessment of financing needs, and streamlined payments across nearly 1,000 pharmaceutical manufacturers.[58] The result: stronger upstream supply chain relationships.[59]

While the literature highlights how data, particularly from frontier technologies, has enhanced the health sector for economic transformation, some African countries are implementing data-driven health initiatives.

In remote and underserved regions, geospatial data combined with drone technology are being used to deliver vaccines, medications, and other critical treatments, contributing to better public health outcomes. Data science, managed by AI and machine learning, has revolutionized diagnostics and routine medical checkups, helping detect and manage cancer, heart disease, diabetes, and even mental health issues more effectively. The importance of clinical trial data and electronic medical records is growing in healthcare, particularly when managed through blockchain systems.[60] These technologies not only ensure data integrity but also allow healthcare payers and providers to access trusted information.

Data from surgical robots, powered by AI, machine learning, and deep learning, are assisting surgeons with complex procedures by improving precision and enabling the early detection of diseases through enhanced image analysis.[61] Additionally, data from IoT devices support real-time health monitoring, especially through intelligent remote patient monitoring systems, which are becoming essential tools for chronic disease management and post-surgery care.

While the literature highlights how data, particularly from frontier technologies, has enhanced the health sector for economic transformation, some

African countries are implementing data-driven health initiatives. In the United Republic of Tanzania, the health sector has benefitted from innovative data systems such as the Tanzania Immunization Registry, implemented in 2016 as part of the Better Immunization Data Initiative. The electronic immunization registry is integrated with the vaccine supply chain system. Health workers in more than 3,700 facilities use a digital platform (with tablets and barcode scanners) to record childhood immunizations and track vaccine stock. This data-driven approach has improved the accuracy and timeliness of immunization records, making it easy to identify children who miss vaccines and target follow-ups. Early analyses showed increases in on-time vaccination rates, as clinics can send reminders and ensure no child "falls through the cracks." It also reduced vaccine waste by monitoring inventory in real time.[62]

Education. Data quality and trust are paramount in identity systems and education records, which—while not "statistics" in the publishing sense—are foundational data for many indicators (such as school enrolment and literacy). In education and vocational training, the demand for data-driven technologies continues to grow. In 2021, the Rwanda Education Board introduced an AI-supported placement system to assist in allocating students to public secondary schools based on their national exam performance and school preferences. While the system aimed to increase efficiency and fairness, some schools and parents raised concerns about misplacement and lack of transparency in how decisions were made. As a result, the board updated its school database and synchronized it with real-time enrolment figures, a public dashboard was introduced to allow students and parents to verify placement results, and the system's algorithm rules were published to enhance trust and understanding. This case demonstrates how transparency, citizen feedback, and data validation can improve fairness in automated public service delivery.[63]

A wide range of data frontier tools have been developed to enhance the quality of teaching and learning. These include interactive smart boards, e-textbooks, educational technologies, augmented and virtual reality platforms, metaverse environments, and wearable technologies. All these innovations, made possible by data, are reshaping how education is delivered. They not only simplify the teaching and learning process for both educators and students but also expand access to quality education and advanced training opportunities that were previously limited or unavailable, especially in remote or underserved areas. Ethiopia introduced a blockchain database for identity and education records, embarking on a high-profile project with Input Output Hong Kong, the company behind the Cardano blockchain platform, to create a blockchain-based student and teacher ID and academic record system. Announced in 2021, this Ministry of Education–led initiative aims to issue 5 million secondary school

students a blockchain-based digital identity that will carry their education records throughout their academic life.[64] The benefits envisioned include reducing fraud (no fake degrees), increasing efficiency in recordkeeping (no lost files), and giving students a portable, trusted record of their qualifications, which could even be used internationally.[65] If successful, Ethiopia's project could be expanded beyond education to broader digital identity, which is fundamental for many public services and statistics.

The United Republic of Tanzania is another example of successfully applying data-driven decision-making in education. The country introduced school-based surveys and analytics to improve student wellbeing and learning outcomes and has been developing an education management information system that collects detailed school data (enrolment, attendance, exam results, and infrastructure) on a digital platform. The platform allows education policies to be more inclusive—ensuring girls, rural students, and other groups are not left behind.[66]

Data from frontier technologies have enabled governments to expand their tax base, reduce tax fraud, and combat tax avoidance more effectively. Big data also play a key role in combating corruption, conducting trend analysis, and producing more accurate economic forecasts.

Governance. Data from frontier technologies have enabled governments to expand their tax base, reduce tax fraud, and combat tax avoidance more effectively. Big data also play a key role in combating corruption, conducting trend analysis, and producing more accurate economic forecasts. Blockchain data in particular contributes to transparency and helps create sustainable incentive systems, while IoT database platforms support real-time monitoring of government activities and service delivery. Data combined with robotics have markedly improved personnel safety in the field, especially in high-risk environments, by supporting reconnaissance and surveillance missions.[67] Similarly, data from robotics integrated with AI and machine learning have an important role in military operations, supporting surveillance, reconnaissance, and bomb disposal and enabling informed decisionmaking based on real-time intelligence.[68]

Cybersecurity and protecting critical infrastructure are key governance areas in harnessing data, especially data from frontier technologies, for economic transformation. Some African countries, including the United Republic of Tanzania and Rwanda, have developed a government cybersecurity strategy. Recognizing escalating cyber risks, Tanzania's aims

to secure the country's digital infrastructure and data assets and ensure a "secure and resilient cyberspace for efficient and effective delivery of public services." It lays out objectives such as enhancing protection of government information and communications technology systems, improving cyber incident response, building cybersecurity skills, and fostering international cooperation on cyber threats. The country has taken measures to monitor and guard critical systems (including National Bureau of Statistics databases) against intrusion. By 2024, Tanzania's efforts were reflected in improved rankings on the Global Cybersecurity Index in Africa.[69] Still, recent incidents have prompted even more stringent actions: the government has upgraded network firewalls, instituted security audits across ministries, and run public awareness campaigns on cyber hygiene. These steps aim to protect government-held data, as well as the broader digital economy, from disruption, thereby maintaining trust in digital services and upholding national sovereignty in the digital realm.[70]

Rwanda was among the African countries most targeted by malware attacks in 2023, with 46 per cent of industrial control system computers registering malicious activity. In response, the country established the Rwanda Computer Security Incident Response Team under the National Cyber Security Authority.[71] The team operates 24/7 and coordinates with the government and the private sector to detect, respond to, and mitigate cybersecurity incidents. The use of data in governance for economic transformation is not limited to cybersecurity. The country adopted a national data-sharing policy in 2025, marking a major milestone in the country's data governance journey. The policy will foster greater collaboration among government institutions, reduce duplication of efforts, build a skilled workforce capable of addressing frontier digital challenges, and unlock the full value of data to support improved, evidence-based decisionmaking.[72]

Data-driven innovations in finance can boost agricultural development by improving access to credit and insurance. Such indirect effects of data from frontier technologies are often multilayered, reflecting the deep interconnection between sectors, and can result in broad spillover effects.

Spillover effects. The analysis above has shown the direct impact of data from frontier technologies on sectoral performance. But these data also exert indirect effects across the economy. For example, data-driven innovations in finance can boost agricultural development by improving access to credit and insurance. Such indirect effects of data from frontier technologies are often multilayered, reflecting the deep interconnection between sectors, and can result in broad spillover effects. Even sectors that seem unrelated to data from frontier technologies may benefit indirectly through these links. In this way, data from frontier technologies can enhance domestic production more than proportionally. These spillovers are not limited to national borders; because national sectors are linked to those in other countries, regional integration can amplify the benefits, forming regional value chains of frontier technologies. At a broader level, this extends into global value chains, enhancing cooperation and technology diffusion worldwide.

CONCLUSION

Africa's economic growth remains volatile, and data are increasingly recognized as both a diagnostic tool and a strategic asset for driving transformation across key sectors. Data characteristics offer business opportunities for African economies. Being a defining resource in the digital era and described as the "new oil," data are renewable and multiply in value when analysed and shared. Data, unlike oil, are not based on natural endowment and can be developed owing to strategic approaches and business initiatives. With a youthful population, expanding mobile penetration, and growing innovation ecosystems, Africa is poised to harness the data revolution, leveraging frontier technologies with suitable investment in infrastructure, skills, and regulation.

Moreover, data play a crucial role in various frontier technologies. Just as oil has long been a critical raw material for the economy, data have become essential for powering frontier technologies (data becomes the "new oil" powering technological advancement). There is a two-way relationship between data and frontier technologies: data serve as the foundational input for these technologies, and frontier technologies process and transform data into more structured, secure, and usable forms. Chapter 2's empirical results highlight a critical distinction between readiness to adopt frontier technologies and readiness to benefit from them. While many African countries have made progress in data-generation systems, these advances have not consistently translated into sustained productivity gains. Adoption without complementary capabilities can yield weak or even negative outcomes, as firms and public institutions struggle to integrate new technologies into production processes, decisionmaking, and service delivery.

This gap arises because the capacity of frontier technologies to generate transformative outcomes depends not only on the availability of data but critically on data readiness, including quality, representativeness, interoperability, governance, and institutional use of those data. While data volumes are increasing across Africa, gaps in data readiness continue to constrain effective advanced analytics and AI.

Where skills formation, institutional quality, and productive capacity lag, data-driven technologies tend to remain confined to pilots or parallel systems, raising costs without improving efficiency. In this context, data governance reforms—covering standards, interoperability, privacy, and statistical capacity—are not ancillary technical issues but core productivity enablers. They determine whether digital and data-driven technologies are embedded in operational systems and translated into durable efficiency gains, rather than remaining isolated innovations with limited economy-wide impact.

African countries have made considerable progress in producing data and statistics to inform decisionmaking in the region and beyond, particularly in official statistics. With the data revolution, Africa is increasingly integrating into the data value chain. But systemic constraints still limit the emergence of strong and inclusive data ecosystems. Two critical challenges stand out: the data value chain, which still needs to be developed, and the risk of biased or incomplete data. This risk is particularly salient for AI and machine learning, where biased, unrepresentative, or externally sourced datasets may distort outcomes, reduce predictive validity, and lead to unintended exclusion when models are deployed in African contexts. Broader structural, institutional, and social factors compound these issues.

Beyond data, the effective use of frontier technologies increasingly depends on access to affordable computing infrastructure, cloud services, reliable energy, and technical support systems. Limited access to high-performance computing and scalable cloud resources remains a binding constraint for many African institutions seeking to move from descriptive analytics to advanced AI applications.

Addressing these challenges requires prioritized action in three areas: strengthening data and artificial intelligence governance frameworks to ensure trust, equity, and data sovereignty; investing in interoperable data infrastructure, computing capacity, and specialized skills across the data value chain; and fostering regional coordination to enable cross-border data sharing, scale, and innovation under regional initiatives such as the AfCFTA.

REFERENCES

Adjane, D. D., O. D. Kothalkar, and P. M. Vaidya. 2023. "Advance Automation System." *International Research Journal of Modernization in Engineering Technology and Science* 5 (12).

AU (African Union). 2020. *Digital Transformation Strategy for Africa (2020–2030)*. African Union Commission. https://au.int/sites/default/files/documents/38507-doc-dts-english.pdf.

AU (African Union). 2024. *Data Policy Framework*. African Union Commission. https://au.int/sites/default/files/documents/42078-doc-DATA-POLICY-FRAMEWORKS-2024-ENG-V2.pdf.

Baldock, D. 2022. "Designing the Perfect Supply Chain: Is Regionalization the Answer?" Escatec, March 24.

BIO (Biotechnology Innovation Organization). 2025. "What Is Biotechnology?" https://www.bio.org/what-biotechnology.

Blackduck. 2025. "Blockchain: Six Considerations for Securing Your Software Supply Chain." https://www.blackduck.com/glossary/what-is-blockchain.html.

CIGI (Centre for International Governance Innovation). 2021. "Blockchain-Based ID Project in Ethiopia." December 7. https://www.cigionline.org.

CoinDesk. 2023. "Ethiopian Education Minister Confirms Cardano Blockchain Partnership." By M. Hochstein and A. Baydakova. April 30. Updated May 9, 2023. https://www.coindesk.com/business/2021/04/30/ethiopian-education-minister-confirms-cardano-blockchain-partnership.

DataCamp. 2023. "Artificial Intelligence (AI) vs Machine Learning (ML): A Comparative Guide." By M. Crabtree. September 21. https://www.datacamp.com/blog/the-difference-between-ai-and-machine-learning.

Deloitte. 2017. *Using Blockchain to Drive Supply Chain Innovation.*

Frontier Technologies Hub. 2025. "How Three Frontier Technologies Are Transforming Humanitarian Aid Supply Chains." By K. Rowe. https://www.frontiertechhub.org/insights/three-frontier-technologies-transforming-humanitarian-supply-chains.

Global Partnership for Sustainable Development Data. 2022. "New Analysis Shows Every Dollar Invested in Data Systems Creates an Average of $32 in Economic Benefits." Global Partnership for Sustainable Development Data. https://www.data4sdgs.org/news/new-analysis-shows-every-dollar-invested-data-systems-creates-average-32-economic-benefits.

Great Learning. 2025. "Data Science vs Machine Learning and Artificial Intelligence: The Difference Explained." By M. Chatterjee. January 16. https://www.mygreatlearning.com/blog/difference-data-science-machine-learning-ai/.

IBM. 2024. "What Is Artificial Intelligence (AI)?" By C. Stryker and E. Kavlakoglu. August 9. https://www.ibm.com/think/topics/artificial-intelligence.

IDC (International Data Corporation). 2022. *Worldwide Global DataSphere Forecast.* IDC Research.

Intel. n.d. "Types of Robots: How Robotics Technologies Are Shaping Today's World." https://www.intel.com/content/www/us/en/learn/types-of-robots.html.

ILO (International Labour Organization). 2018. *Digital Labour Platforms and the Future of Work: Towards Decent Work in the Online World.* International Labour Office, Geneva.

Interactive Advertising Bureau (IAB) & PwC. (2024). *Internet Advertising Revenue Report: Fullyear 2023 results*. https://www.iab.com/wp-content/uploads/2024/04/IAB_PwC_Internet_Ad_Revenue_Report_2024.pdf

Jones, C. I., and C. Tonetti. 2020. "Nonrivalry and the Economics of Data." *American Economic Review* 110 (9): 2819–2858.

Liebal, U. W., R. Schimassek, I. Broderius, N. Maaßen, A. Vogelgesang, P. Weyers, and L. M. Blank. 2023. "Biotechnology Data Analysis Training with Jupyter Notebooks." *Journal of Microbiology & Biology Education* 24 (1): e00113-22. https://doi.org/10.1128/jmbe.00113-22.

McKinsey & Company. 2024a. "What Is Blockchain?" June 6. https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-blockchain.

McKinsey & Company. 2024b. "What Is the Internet of Things (IoT)?" May 28. https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-the-internet-of-things.

Moroccan Customs. 2020. "Dematerialization of Customs Procedures: Feedback from Moroccan Customs." *WCO News* 94. https://mag.wcoomd.org/magazine/wco-news-94/dematerialization-of-customs-procedures-morocco/.

NEPAD (New Partnership for Africa's Development). 2022. "Exploring Blockchain-Enabled Technologies in Africa's Trade." AUDA-NEPAD Blog. https://www.nepad.org.

NM Partners. 2022. "The United Nations to Enable Women-Led Digital Businesses in Anglophone Africa Scale Up and Expand to New Markets." *Nairametrics*, August 16. https://nairametrics.com/2022/08/16/the-united-nations-to-enable-women-led-digital-businesses-in-anglophone-africa-scale-up-and-expand-to-new-markets/.

OECD (Organisation for Economic Co-operation and Development). 2021. *Artificial Intelligence, Machine Learning and Big Data in Finance: Opportunities, Challenges, and Implications for Policy Makers.* OECD Publishing, Paris. https://www.oecd.org/finance/artificial-intelligence-machine-learning-big-data-in-finance.htm.

Oracle. 2021. "What Is Blockchain?" September 27. https://www.oracle.com/africa/blockchain/what-is-blockchain/.

Precedence Research. *Data Monetization Market Size, Share and Trends 2025 to 2034*. November 27, 2025. https://www.precedenceresearch.com/data-monetization-market

Repsol. 2023. "All About Biotechnology: Technology and Innovation to Improve Our Quality of Life." September 11. https://www.repsol.com/en/energy-move-forward/innovation/biotechnology/index.cshtml.

Rice University. 2023. "Data Science vs. Artificial Intelligence & Machine Learning: What's the Difference?" Rice Engineering and Computing, Department of Computer Science. April 13. https://csweb.rice.edu/academics/graduate-programs/online-mds/blog/data-science-vs-ai-and-ml.

Shukla, S., K. Bisht, K. Tiwari, and S. Bashir. 2023. *Data Economy in the Digital Age.* Springer, Singapore.

Shumailov, I., Z. Shumaylov, Y. Zhao, N. Papernot, R. Anderson, and Y. Gal. 2024. "AI Models Collapse When Trained on Recursively Generated Data." *Nature* 631: 755–759. https://doi.org/10.1038/s41586-024-07566-y.

Soori, M., B. Arezoo, and R. Dastres. 2023. "Artificial Intelligence, Machine Learning and Deep Learning in Advanced Robotics: A Review." *Cognitive Robotics* 3: 54–70. https://doi.org/10.1016/j.cogr.2023.04.001.

Sparity. 2023. "Data Analytics in Biotechnology: Unleashing the Power of Insights. Blogs, Biotech, Data." May 23. https://www.sparity.com/blogs/data-analytics-in-biotechnology-unleashing-the-power-of-insights/.

Stanford University. 2023. *The Stanford Emerging Technology Review 2023: A Report on Ten Key Technologies and Their Policy Implications.* https://setr.stanford.edu/technology/robotics/2023.

Supply Chain Brain. 2018. "How Intelligent Business Networks Will Empower Tomorrow's Autonomous Supply Chains." April 9.

TechTarget. 2025a. "What Is Blockchain? Definition, Examples and How It Works." https://www.techtarget.com/searchcio/definition/blockchain.

TechTarget. 2025b. "What Is IoT (Internet of Things)?" https://www.techtarget.com/iotagenda/definition/Internet-of-Things-IoT.

TechTarget. 2025c. "What Is Robotics?" By K. Yasar and K. T. Hanna. Published September 4, 2024. https://www.techtarget.com/whatis/definition/robotics.

TechTarget. 2025d. "What Is a Smart City?" By G. Wright, S. Shea, and E. Burns. Published March 4, 2025. https://www.techtarget.com/iotagenda/definition/smart-city.

The Citizen (Tanzania). 2024. "Tanzania Leads Africa in 2024 Global Cybersecurity Rankings." https://www.thecitizen.co.tz/tanzania/news/national/tanzania-leads-africa-in-2024-global-cybersecurity-rankings-4765000.

TigerData. 2024. "Understanding IoT (Internet of Things)." By A. Tavares. May 28. https://www.tigerdata.com/learn/understanding-iot-internet-of-things.

UNCTAD (United Nations Conference on Trade and Development). 2022. *Economic Development in Africa Report 2022: Rethinking the Foundations of Export Diversification in Africa–The Catalytic Role of Business and Financial Services.* United Nations, Geneva.

UNCTAD (United Nations Conference on Trade and Development). 2023a. *Economic Development in Africa Report 2023: The Potential of Africa to Capture Technology-Intensive Global Supply Chains.* United Nations, Geneva.

UNCTAD (United Nations Conference on Trade and Development). 2023b. *Global Report on Blockchain and Its Implications on Trade Facilitation Performance.* United Nations, Geneva.

UNCTAD (United Nations Conference on Trade and Development). 2025. *Technology and Innovation Report 2025: Inclusive Artificial Intelligence for Development.* United Nations, Geneva.

UNCW (University of North Carolina Wilmington). n.d. Creating a Narrative With Reports and Data Graphics. Online Degree Programs, UNCW. https://onlinedegree.uncw.edu/programs/business/ms-business-analytics/creating-a-narrative-with-reports/.

Wiseman, J. 2019. *The Case for Government Investment in Analytics.* September.

World Economic Forum. 2016. "$100 trillion by 2025: The Digital Dividend for Society and Business." Press release, January 2016. https://www.weforum.org/press/2016/01/100-trillion-by-2025-the-digital-dividend-for-society-and-business/.

Wood, M. 2019. "Optimizing Supply Chain Opportunities in Africa through Innovative Financing and Digital Platforms." In *Economic Development in Africa Report 2023*. UNCTAD, Geneva.

Zuboff, S. 2019. *The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power*. PublicAffairs.

END NOTES

1 Data are understood broadly aany meaningful information that can be stored, transmitted, and processed—including raw observations, measurements, symbols, models, and even codified expert knowledge. Within this broad universe, statistics are derived data: they are data produced through formal statistical operations (aggregation, estimation, inference, modelling) applied to other data, yielding quantities such as indicators, coefficients, prediction outputs, and confidence intervals. All statistics are therefore data in the data economy sense, but not all data are statistics. In current policymaking and business processes, data and statistics are both instrumental in their different capacities to inform and guide decisionmaking, monitoring, and evaluation.

2 Gaps in data and statistics refer to structural and systemic weaknesses in a country's data ecosystem, encompassing both the lack or insufficiency of relevance required for available data to inform decisionmaking across economic, social, technological, and governance spheres and deficiencies in the timeliness, frequency, and update cycles of available data and statistics, which limit their ability to effectively respond to current, emerging, and forward-looking policy and decisionmaking needs, particularly in fast-evolving domains such as frontier technologies.

3 UNCW n.d.

4 World Economic Forum 2016

5 Jones and Tonetti 2020.

6 AU 2024.

7 Shumailov et al. 2024.

8 IDC 2022.

9 A Tier III data centre has multiple paths for power and cooling and systems so that it can be updated and maintained without being taken offline.

10 ILO 2018.

11 Interactive Advertising Bureau (IAB) & PwC (2024).

12 Shukla et al. 2023.

13 Precedence Research (2025).

14 See, for example, Zuboff (2019).

15 Global Partnership for Sustainable Development Data (June 2023).

16 Jane Wiseman, The Case for Government Investment in Analytics, September 2019.

17 A contemporary form of domination in which powerful states and large technology corporations, mainly from the Global North, control the digital infrastructure, platforms, and data of other countries, especially in the Global South, in ways that reproduce colonial-style dependency and extraction of value from these societies.

18 McKinsey 2024a.

19 TechTarget 2025a.

20 Blackduck 2025; Deloitte 2017; Oracle 2021; UNCTAD 2022, 2023a.

21 Blackduck 2025; TechTarget 2025a.

22 Baldock 2022; McKinsey 2024b; TechTarget 2025b; TigerData 2024.

23 Edge processing refers to data analysis performed locally on devices or near the data source instead of relying on the cloud.

24 McKinsey 2024b.

25 Baldock 2022.

26 Intel n.d.; TechTarget 2025c.

27 Stanford University 2023.

28 Rice University 2023.

29 OECD 2021.

30 IBM 2024; Datacamp 2023; Great Learning 2025; Soori et al. 2023; Rice University 2023.

31 Deep learning is a type of machine learning that uses multi-layered neural networks to automatically learn patterns from large amounts of data.

32 Structured data are organized in a fixed format such as tables with rows and columns, while unstructured data have no predefined structure, such as text, images, audio, or videos.

33 McKinsey 2024a.

34 Adjane et al. 2023.

35 Repsol 2023.

36 Liebal et al. 2023; Sparity 2023.

37 TechTarget 2025d.

38 TechTarget 2025d.

39 The areas in which data generated through frontier technologies can be leveraged to enhance performance extend beyond those already mentioned; they also encompass climate change, environmental sustainability, and gender-related issues.

40 OECD 2021.

41 ECA survey response from the Rwanda National Institute of Statistics.

42 OECD 2021.

43 ECA survey response from the Rwanda National Institute of Statistics.

44 ECA survey response from Tanzania's National Bureau of Statistics.

45 ECA survey response from Statistics South Africa.

46 UNCTAD 2023a.

47 UNCTAD 2023a.

48 UNCTAD 2025.

49 Soori et al. 2023.

50 Soori et al. 2023.

51 https://www.shuttlers.co.

52 NM Partners 2022.

53 Soori et al. 2023.

54 AU 2020.

55 UNCTAD 2023a

56 UNCTAD 2023b.

57 Moroccan Customs 2020; UNCTAD 2023b.

58 UNCTAD 2023a.

59 Wood 2019.

60 Blackduck 2025.

61 Soori et al. 2023.

62 ECA survey response from Tanzania's National Bureau of Statistics.

63 ECA survey response from Rwanda National Institute of Statistics.

64 CIGI Online, 2021.

65 CIGI Online, 2021; CoinDesk 2023.

66 ECA survey response from Tanzania's National Bureau of Statistics.

67 Intel n.d.

68 Soori et al. 2023.

69 The Citizen 2024.

70 ECA survey response from Tanzania's National Bureau of Statistics.

71 ECA survey filled by Rwanda National Institute of Statistics.

72 ECA survey filled by Rwanda National Institute of Statistics.

73 Shukla et al. 2023.

74 A contemporary form of domination in which powerful states and large technology corporations, mainly from the Global North, control the digital infrastructure, platforms, and data of other countries, especially in the Global South, in ways that reproduce colonial-style dependency and extraction of value from these societies.

CHAPTER 5 LESSONS LEARNED, OPPORTUNITIES, CHALLENGES, AND RISKS IN ADOPTING FRONTIER TECHNOLOGIES IN AFRICA

The rapid advancement of frontier technologies offers new opportunities for Africa's economic transformation. But frontier technologies are not new to the continent. Several African countries have already been deploying frontier technologies in sectors such as health, agriculture, manufacturing, and financial services—demonstrating the continent's capacity and ongoing engagement with global technological progress.

A complex set of constraints, including fragmented policies, insufficient government support, financial and investment barriers, infrastructure deficits, gaps in human and institutional capacity, inability to access regional and international market opportunities,[1] and issues related to equality and inclusion limit the adoption and impact of frontier technologies by African governments, businesses, and communities. This restricts the positive impact these frontier technologies could have on a broad range of stakeholders, including citizens, entrepreneurs, and public and private institutions. In addition to these challenges, adopting frontier technologies comes with considerable risk. These include concerns related to cybersecurity, data privacy, technological unemployment, digital divide, dependence on foreign technology, regulations and ethics, financial and investment risk, and environmental impact. A comprehensive understanding of these challenges and risks is crucial for developing strategies that can unlock the transformative potential of frontier technologies in Africa for the benefit of all.

Chapter 2's dynamic analysis confirms that frontier technologies do not automatically translate into productivity or growth. Skills development and industrial activity consistently emerge as the strongest and most durable channels, while finance and information and communication technology infrastructure play supporting roles. This explains why many technology initiatives in Africa succeed at the pilot stage but fail to scale or deliver economy-wide impacts.

Using a systemic categorization, this chapter provides a framework for rethinking how Africa can navigate and address constraints, prioritizing equity, scalability, and sustainability, as outlined in the AU Digital Transformation Strategy.[2] Building on the groundwork established in the previous chapters, this chapter also presents lessons from practical case studies of challenges faced by frontier technology initiatives in various sectors across the continent. Furthermore, it discusses unique opportunities on the continent that have the potential for scalability and sustainability in promoting economic inclusion and equity as countries embrace frontier technologies. The chapter also explores gender and youth perspectives, including issues of human capital development through approaches such as mapping the share of graduates in African countries across different sectors, notably science, technology, engineering, and mathematics (STEM) and information and communication technology.

LESSONS FROM SUCCESSFUL INITIATIVES

Numerous studies, including the findings in chapter 2 and 3 of this report, indicate that technological innovation alone does not ensure successful frontier technology programmes and initiatives in Africa. Elements such as infrastructure, digital literacy investment, technical support, adequate financing, and established policy and regulatory frameworks also play major roles. The empirical analysis in chapter 2 provides a unifying explanation for why the outcomes of frontier technology initiatives have varied widely across countries and sectors. The results indicate that productivity and income gains are most durable when technology adoption is coupled with skills development and industrial activity. By contrast, information and communication technology expansion alone generates limited and sometimes short-lived effects, consistent with the observation that many initiatives deliver visible improvements in access or service delivery but struggle to generate economy-wide productivity transformation.

This provides an evidence-based lens for interpreting the case studies that follow. Successful initiatives tend to be those that build human capital and institutional capability alongside technology or embed technology adoption within productive sectors and value chains, where scale, learning, and spillovers are possible. Conversely, initiatives that focus narrowly on digital tools without addressing skills, institutional effectiveness, or productive capacity may show early gains but weaker medium-term impacts.

Successful initiatives tend to be those that build human capital and institutional capability alongside technology or embed technology adoption within productive sectors and value chains, where scale, learning, and spillovers are possible.

Several successful initiatives across key sectors demonstrating how these factors contribute to positive outcomes are given below.

ZANZIBAR'S DIGITAL HEALTH ID SYSTEM

Zanzibar is transforming its healthcare by moving from free services to a social health insurance system. Central to this change is Kadi ya Matibabu, a digital health card that gives each citizen a unique ID and connects them to clinics, making healthcare use and costs easy to track in real time. This system aims to boost transparency, streamline operations, and guide funding decisions based on data.

The Kadi ya Matibabu programme has achieved a 92 per cent enrolment rate, involving approximately 1.6 million residents across all 11 districts and 268 health facilities.[3] Outpatient visits have increased by 15 per cent, and patient information processing times have dropped by 35 per cent. More than 500,000 medical transactions a year are recorded through integration with the national Matibabu Information System and the Ministry of Health's electronic records. Quality improvements are evident, with more than 800 digital quality improvement plans developed using the PharmAccess SafeCare model, resulting in a 20 per cent rise in facility compliance scores over the past year.

This integrated approach helps the government better allocate resources, ensures fair access to services, and supports evidenced-based policy decisions as Zanzibar works toward universal health coverage. The partnership between the Ministry of Health and PharmAccess has rolled out SafeCare–based quality improvement plans with facility-specific roadmaps for hospitals and clinics on what to fix, in what order, and how to track progress across all districts, providing digital plans, an online resource library, and benchmarking tools for ongoing facility progress.[4]

SOUTH AFRICA'S BMW PLANT

Frontier technologies are transforming Africa's manufacturing sector. Since 2015, the BMW plant in Rosslyn, South Africa, has experienced substantial advancements by integrating Industry 4.0 technologies, focusing primarily on automation. The plant employs Internet of Things (IoT)–enabled robots and uses artificial intelligence (AI)-assisted inspections, incorporating visual quality checks powered by AI, as well as remote software updates. These enhancements have improved quality control, system reliability, and accuracy and while minimizing waste.[5]

As a result, Rosslyn has become BMW's major global supplier of the X3 PHEV, exemplifying how Africa can strengthen its position in the global automotive value chain. The impact of these automation initiatives is quantifiable, with production capacity increasing from approximately 71,353 units in 2015 to a cumulative 403,114 units of the third-generation X3 in 2024, a 5.6-fold increase.[6] Employment figures also reflect positive trends: direct employment rose from about 2,900 in 2015 to approximately 3,000 in 2023, while indirect jobs expanded from around 5,000 to more than 49,000.[7]

Frontier technologies are transforming Africa's manufacturing sector. Since 2015, the BMW plant in Rosslyn, South Africa, has experienced substantial advancements by integrating Industry 4.0 technologies, focusing primarily on automation.

By leveraging frontier technologies, Rosslyn transitioned from traditional sedan assembly lines (3 Series) to a fully retooled facility for the X3 PHEV. This leap enabled the plant to close the technology gap rapidly, positioning Rosslyn alongside BMW's newest plants in Europe by achieving Industry 4.0–ready production capabilities.[8]

Photo: Aerial view of the BMW Plants-Rosslyn, South Africa. © Umbra Lab, Inc., CC BY 4.0, via Wikimedia Commons

TOGO'S LAND INFORMATION SYSTEM

Togo digitized its land registry using a modern land information system built on geographic information system mapping tools, relational geospatial databases, electronic document management systems, and web-based e-government platforms, all integrated with the national digital ID. As of 2022, the country has digitized more than 99 per cent of land titles, and the land registry is now fully dematerialized.[9]

Holding a legal land title in Togo increased the probability of agricultural investment by 13 per cent, and where customary rights (as opposed to formal title) existed, the increase was 21 per cent compared with no recognized rights. Digitized land rights are strongly correlated with increased investment by farmers, which in turn raises productivity, implying economic benefits at the household and agricultural sector levels.[10] Togo's digital land registry facilitates secure land title registration, boosting farm-level investment and productivity, which then raises agricultural output, rural incomes, and food security.

EGYPT'S E-TAX SYSTEM

In 2022, Egypt rolled out a national e-invoicing and e-receipt mandate under the e-tax system, requiring all taxpayers to issue electronic tax invoices, and in 2023, it required entities to issue electronic invoices in order to import or export or deal with customs.[11] In 2025, the Egyptian Tax Authority (ETA) reported that its digital platforms held 3.5 billion e-invoices and receipts, a massive database that the government says it will use for better tax administration, compliance monitoring, and economic analysis.[12] Overall tax revenue growth reached about 30 per cent in the 2023/2024 fiscal year, with income tax revenue up 36 per cent and value added tax revenue up 23 per cent, due in part to e-tax measures such as the unified payroll tax system and e-invoicing and e-receipts. Average value added tax refund times have fallen to 24 days from the 45 days stipulated in law, indicating a concrete efficiency gain for businesses' cash flow.[13]

There is emerging evidence of impact on compliance and enforcement. Between 2020, when the e-invoice system was launched, and 2023, Egypt's tax authorities collected EGP 8.8 billion ($286 million) from 7,305 tax evasion cases that presumably would have been harder to detect before the shift from paper to digital invoicing.[14] A positive, statistically significant relationship exists between adopting the electronic invoice tax system and taxpayer compliance.[15]

LESSONS FROM UNSUCCESSFUL INITIATIVES

The success stories highlighted above, along with those in chapter 3, clearly demonstrate the pivotal role of frontier technologies in driving transformation across multiple sectors in Africa. The case studies underscore how strategically adopting frontier technologies—from digital identity management and automation to artificial intelligence and IoT—can yield tangible, large-scale benefits in health, manufacturing, and beyond.

But for policymakers, implementers, and stakeholders to learn from past experiences, anticipate potential risks, and design more effective interventions, it is equally important to consider examples where projects have faced setbacks or failed. This reflective approach ensures that investment in technology and development is effective and avoids repeating previous mistakes. The examples below illustrate how the absence or weakness of critical enablers can undermine the success of technology-driven projects.

AGRICULTURE

Ghana launched the Esoko platform in 2005 to provide farmers with direct access to information on weather updates, market prices, and agronomic advice on their phones. Leveraging frontier technologies such as mobile communications, cloud-based data analytics, and SMS-based information delivery, Esoko aimed to empower smallholder farmers by increasing their bargaining power while reducing harvest losses. The platform harnessed mobile connectivity to disseminate real-time market and weather data while using digital tools for two-way communication and feedback between farmers and extension agents, ensuring timely access to critical agricultural information and advice.[16] Despite promising uptake in the initial stages, farmers' long-term engagement remained very low. In Northern Ghana, 81.4 per cent of farmers were aware of the digital services available, but only 12.12 per cent had consistently used the services.[17] The primary reasons were low digital literacy, limited internet access, and inadequate technical support. Additionally, unsustainable finance led to financial deficits once donor support was withdrawn, meaning that platforms struggled to generate sufficient revenue from farmers, who were either unwilling or unable to pay for SMS-based services.[18] But opportunities exist to create a digitalization for smallholders that is sensitive to the current and future structural limitations of smallholder agriculture, including low literacy and limited access to digital tools, to ensure agriculture digitalization reaches its full potential in Africa.

TRANSPORT

In Nigeria, IoT and its application in several ride-hailing applications have emerged to compete with established players such as Uber.[19] Founded in 2014, Oga Taxi, was the pioneer indigenous ride-hailing app, offering a local alternative for commuters. Another indigenous app, T-Cap Rides was founded in 2018 and introduced a unique feature allowing passengers to negotiate fares directly with drivers. In 2017, Alpha Rides, also homegrown, sought to disrupt the market with different ride options, including office shuttles and limousines. GoAfrik, which launched Taxigo Nigeria in 2018, aimed to provide a comprehensive logistic platform, including taxi booking and courier services. All these businesses faced challenges related mainly to the frontier technologies used and well-funded foreign competitors such as Uber, inconsistent policies and regulatory hurdles, operational costs, and poor road infrastructure, resulting in high vehicle maintenance costs. These examples illustrate how indigenous ride-hailing platforms may struggle to survive in the absence of strong and sustainable infrastructure and financing.

E-GOVERNANCE

Uganda's biometric National ID system, Ndaga Muntu, was launched in 2014 to create identification for access to social services in Uganda.[20] By 2020, 25.9 million people were registered, but 17.4 million citizens were unregistered due to financial and technological barriers, bureaucratic inefficiencies, and infrastructure gaps.[21] The majority of the unregistered population consisted of women, the

elderly, and minorities, which posed a challenge to accessing healthcare services and welfare benefits.[22] Key challenges associated with the system include insufficient transparency, underdeveloped legal and accountability frameworks, limited system integration, inadequate data protection measures, and the lack of effective remedies for those who are excluded.

EDUCATION

The New Partnership for Africa's Development's E-School Program highlights that achieving lasting impact requires a comprehensive, multi-stakeholder approach that integrates technology, people, finance, and governance. The programme was launched in 2003 to equip 600,000 African schools with computers, internet access, and digital curricula within 10 years.[23] It failed to achieve its goal by 2013 due to several factors, including lack of clear objectives, misalignment among stakeholders, weak institutional capacity, insufficient financial and human resources, funding shortfalls after donor and partners withdrew, failure to establish sustainable financing mechanisms (which hindered scalability and disabled the transition from the pilot to continent-wide implementation), an unreliable electricity supply (which left information and communication technology labs unused or underused, and limited teacher training and support for the programme (resulting in minimal integration of digital tools into the learning process, further hampering the success of the programme).[24]

Kenya's Kissi County Digital Literacy Programme was launched in 2016 to integrate digital technology into education by providing laptops with e-learning content to students in public primary schools across the country. More than 20,000 devices were reportedly distributed to 23,951 schools by 2020.[25] According to an assessment of 250 primary schools in Kissi County, 75.2 per cent of teachers reported difficulty using the computers, highlighting a wide gap in digital skills.[26] This highlights the necessity for capacity building in information and communication technology to develop appropriate skills, knowledge, and attitudes for the effective use of devices and learning support.

The lessons learned matrix in table 5.1 provides a structured approach for synthesizing evidence from diverse countries and sectors on adopting frontier technologies in Africa. Rather than presenting lessons as isolated observations or best practices, the matrix organizes learning around six core pillars that capture the systemic conditions shaping adoption outcomes. The pillars are based on their recurrence, explanatory power, and relevance. By grounding the pillars in cross-cutting patterns, the matrix provides a disciplined basis for synthesizing lessons that are both analytically robust and policy-relevant across African contexts.

The lessons learned matrix in table 5.1 provides a structured approach for synthesizing evidence from diverse countries and sectors on adopting frontier technologies in Africa.

Table 5.1 Lessons learned from adopting frontier technologies in Africa

Political leadership	**Institutional capacity and coordination**	**Financing, public-private partnerships, and fiscal sustainability**	**Sequencing, scalability, and learning**	**Human capital and digital literacy**	**Productivity, structural transformation, and inclusion**
Ensure sustained political leadership, bureaucratic alignment, and institutionalized changes.	Provide strong cross-ministerial and national–subnational coordination.	Structure financing and public-private partnerships to align incentives and allocate risk appropriately.	Sequence actions around enabling foundations and prerequisites.	Scale functional digital literacy and capability for citizens, workers, and small and medium enterprises.	Target adoption that changes firm behaviour and productivity.
Use centre-of-government delivery units to unblock implementation.	Clear institutional mandates across regulation, delivery, and oversight.	Assess full lifecycle fiscal costs, including operations and maintenance and upgrade cycles.	Scale initiatives only where political, fiscal, and institutional readiness exists.	Design inclusion mechanisms to prevent widening divides.	Anticipate employment impacts and manage transitions.
Systematically document and learn from stalled or reversed initiatives.	Develop interoperable standards and shared digital public infrastructure.	Align donor, development finance institution, and private finance with national technology priorities.	Ensure that pilot initiatives have clear criteria for scale, exit, or redesign.	Align skills systems with priority sectors and labour demand.	Link technology adoption to industrial clusters and value chains.
Ensure youth and gender inclusion through political and budgetary commitments.	Build capacity in core functions that enable scaling and enforcement.	Match capital-intensive projects to realistic timelines and fiscal space.	Embed adaptive learning, feedback, and iteration into delivery.	Expand applied and intermediate digital skills at scale.	Integrate informality and spatial inequality into design.
Transparent governance, public communication, and accountability"	Strengthen cybersecurity and data protection institutions to build trust.	Results-based and performance-linked funding.	Use peer learning and regional benchmarking to accelerate diffusion.	Prepare workers for transitions from automation and platformization.	Align skills deployment with sectoral upgrading and firm demand.

Source: ECA elaboration.

IMMENSE OPPORTUNITIES TO PROMOTE ECONOMIC TRANSFORMATION IN AFRICA THROUGH FRONTIER TECHNOLOGIES

Africa is rapidly adopting frontier technologies, such as digital payments, advanced logistics, AI, data-driven platforms, blockchain, cloud computing, IoT, mobile connectivity, and geospatial information systems, which are reshaping the continent's economy and society. This section highlights how these innovations—through initiatives such as the African Continental Free Trade Agreement (AfCFTA) and the integration of digital systems into education, cross-border trade, financial inclusion, agriculture, and resource management—present major opportunities. It provides an overview of how strategically using and governance of these technologies can drive progress towards the Sustainable Development Goals and support equitable, inclusive growth.

IMPLEMENTING THE AFRICAN CONTINENTAL FREE TRADE AGREEMENT

Digital technologies are reshaping industries in Africa and bringing transformative innovations in trade and other cross-border transactions. The AfCFTA provides a game-changing framework to boost trade-led growth, unlock regional value chains, boost competitiveness, and ensure that Africa transitions from supplying raw materials to producing high-value goods and services. AfCFTA implementation is fundamentally supported by a unified digital market framework that requires integrating digital frontier technologies to fully realize the intended benefits. The Africa Digital Trade Protocol plays a pivotal role in this integration. Adopted as part of the AfCFTA's broader strategy, the protocol aims to create a harmonized regulatory environment for digital trade across the continent. It establishes common standards on such issues as cross-border data flows, e-commerce, digital payments, cybersecurity, consumer protection, and digital identity. By reducing regulatory fragmentation and promoting interoperability, the protocol enables African businesses—especially small and medium enterprises—to participate more actively in regional and global digital markets. Frontier technologies are poised to be a transformative force for operationalizing the AfCFTA through the Africa Trade Gateway, a suite of five digital platforms designed as a single window to support and promote African trade and AfCFTA implementation. The gateway digital ecosystem comprises multiple critical enablers within the framework established by the Africa Digital Trade Protocol:

- MANSA, Africa's due diligence platform, provides a single source of primary data for conducting customer due diligence on African entities, financial institutions, corporations, and small and medium enterprises. It also provides a complementary collection of information on investment in Africa, country profiles, and products and services traded by African countries. MANSA's has had a major impact: by consolidating reliable data, it reduces information asymmetry and mitigates risks associated with cross-border transactions. The increased transparency and trust accelerate investment flows, supports compliance with anti–money laundering and counter-terrorism financing standards, and reduces the cost and complexity of due diligence for African businesses and international partners.
- The Pan-African Payment and Settlement System (PAPSS) was established in July 2019 to enable efficient payment for intra-Africa trade in national currencies, promoting intra-Africa trade, minimizing risk and boosting financial integration across Africa, as well as to support AfCFTA implementation. It provides substantial benefits to end users—including businesses, traders, and consumers—by reducing transaction costs through local currency payments, expediting and enhancing the reliability of cross-border transactions, and facilitating greater market access for small and medium enterprises and entrepreneurs. Additionally, the system fosters financial inclusion by integrating unbanked populations into the formal financial sector, strengthens the security and transparency of payment processes, and indirectly contributes to more stable economic conditions by supporting

improved monetary policy with real-time data provided to central banks. The PAPSS network has shown steady growth, with Algeria and Morocco joining in 2025, taking the total number of countries in the network to 18.26

- The TRADAR Club is a member-driven network aimed at empowering international businesses and executives to transform trade and investment in Africa through trusted trade intelligence and advisory services with innovative digital tools and networking opportunities, helping members discover new markets, grow their businesses, save time, access dedicated expert support, post and respond to new business opportunities, network, meet business and trading partners, and the like.
- ATG Connect serves to connect business service providers across Africa. It provides freight and logistics connectivity solutions that allow for frictionless matching of requests with providers on the platform. Customers can obtain quotes for the pickup and delivery of goods to and from any location in Africa at competitive prices.
- The African Trade Exchange Platform is a business-to-business and business-to-government e-commerce platform launched by ECA in May 2022 to help small, medium, and large African businesses tap into new markets in Africa and optimize their supply chains (box 5.1).

Digital technologies are reshaping industries in Africa and bringing transformative innovations in trade and other cross-border transactions.


© Adobe Stock

Box 5.1 Growing trade opportunities with the African Trade Exchange Platform

The African Trade Exchange Platform (ATEX) is a digital tool created by ECA and the African Export-Import Bank with support from the African Union and the African Continental Free Trade Area (AfCFTA) Secretariat to boost trade under the AfCFTA. Part of the Africa Trade Gateway, ATEX is integrated with the Pan-African Payment and Settlement System to simplify cross-border payments and currency conversion and offer affordable and secure transactions. Its main aim is to reduce costs and make intra-Africa trade easier, especially for small and medium enterprises facing high transaction barriers.

ATEX played a crucial role during global supply disruptions from the Ukraine crisis by helping African countries access essential goods such as food, fuel, and fertilizer. By consolidating demand continent-wide, it boosts Africa's market power and lowers procurement costs. The African Export-Import Bank supports ATEX with financial tools that reduce costs and currency risks for vulnerable economies. Partnerships, such as with the World Food Programme's Food and Agricultural Resilience Mission, streamline logistics during crises. Major companies such as the OCP Group and Dangote are interested in joining, and pooled procurement is under way in several countries. These efforts stabilize supply, create jobs in logistics and digital services, increase local revenues, and promote economic diversification and higher incomes across Africa.

ATEX's achievements are attributable to robust institutional collaboration, effective financing mechanisms, and policy coherence within the AfCFTA framework. Engaging key continental organizations such as ECA, the African Export-Import Bank, the AfCFTA Secretariat, and the African Union provides strong governance and essential political backing. The African Export-Import Bank's financial solutions specifically address structural challenges in African trade finance, facilitating broader involvement from both government and the private sector. Additionally, integrating with the Pan-African Payment and Settlement System ensures that the requisite digital infrastructure and payment systems are established, enabling scalable operations across various markets. Collectively, this integrated approach—encompassing policy, finance, and digital infrastructure—cultivates trust and resilience while fostering inclusive access to trade opportunities across Africa's diverse economies.

Scaling ATEX across Africa requires broader participation and integration. Regional economic communities and the AfCFTA Secretariat can deploy ATEX to support businesses, governments, and stakeholders by boosting trade, commerce, and investment. Beyond emergencies, ATEX can connect African suppliers with buyers and strengthen intra-Africa value chains. With greater platform compatibility, more small and medium enterprise involvement, and partnerships in logistics and digital solutions, ATEX could evolve from a crisis tool into a driver of economic growth. The platform also aims to make trade flows more predictable, enhance transparency, reduce transaction costs, and advance AfCFTA's goal of an integrated African market.

Integrating these platforms provides a strong foundation that is crucial for realizing the objectives of the AfCFTA. By digitizing and optimizing the trade value chain—from initial matchmaking and negotiations on ATEX to payment and settlement via PAPSS—these systems substantially lower barriers to entry for African enterprises. This strategy promotes financial inclusion, increases transparency, and contributes to a unified continental market. By leveraging frontier technologies, the AfCFTA is building the digital infrastructure needed to sustain intra-Africa trade, economic growth, and industrialization across the continent.

The African Medical Supplies Platform, a joint initiative of the African Union's African Centre for Disease Control, ECA, the African Export-Import Bank, and African Union Special Envoy Strive Masiyiwa—launched to ensure equitable access to medical supplies during the Covid-19 pandemic—employs aggregated demand, transparent pricing, and efficient logistics similar to the principles implemented by ATEX. Looking ahead, adopting frontier technologies such as blockchain can fast-track the AfCFTA implementation by providing a tamper-proof digital ledger for cross-border transactions and regulatory compliance, which increases trust and transparency among participating countries. Additionally, blockchain can enhance supply chain traceability and anti-fraud measures, making it easier to monitor the movement of goods and verify their origin, quality, and compliance with standards.

IMPROVING EDUCATION OUTCOMES

Education has a major economic value. The African e-learning market was estimated at $3.4 billion in 2024 and is expected to reach $7.7 billion by 2033; more than 60 per cent of universities in Africa offer online programmes.[27] This does not include those accessing specialized, shorter courses at top universities abroad to learn the specific skills needed to compete in global online job marketplaces. Frontier technologies present Africa's growing youth population with more opportunities to learn and acquire innovative skillsets, narrowing existing gaps. Frontier technologies, especially AI, offer a powerful opportunity to transform education in Africa, making it more accessible, affordable, and responsive to the continent's unique needs.

Frontier technologies offer innovative solutions to address the shortage of teachers, learning materials, libraries, laboratories, and role models, as well as ways to overcome language barriers, among other challenges. In addition to addressing the quantity of teachers, these technologies can also enhance the quality of teaching. For example, online training platforms, virtual classrooms, and AI-powered professional development tools can help educators improve their skills, stay updated with the latest teaching methodologies, and share best practices across regions. Given Africa's linguistic diversity (more than 2,000 languages), AI language models are

Frontier technologies offer innovative solutions to address the shortage of teachers, learning materials, libraries, laboratories, and role models, as well as ways to overcome language barriers, among other challenges. In addition to addressing the quantity of teachers, these technologies can also enhance the quality of teaching.

being explored to translate open education resources into local languages at scale. The Masakhane project, a pan-African research effort, uses AI to machine translate math and science lessons from English or French into Amharic, Hausa, and Swahili, among others.[28] This effort brings indigenous knowledge production and integration of African languages into the global digital arena by drastically reducing the cost of translation.[29] The community-participatory nature of such initiatives creates representative and scalable datasets, thereby increasing human capital development and laying the foundation for future wage and income growth on the continent.

Machine learning for predictive analysis enables learners and educators to identify challenges and students with learning difficulties. In Kenya, one education nongovernmental organization piloted a machine learning model to identify students at risk of dropping out based on such factors as irregular attendance or low academic scores.[30] The model's predictions serve as an early warning system that can allocate limited resources (counsellors, grants, and the like) to the students who need them most and thus improve student retention.[31]

Digital tools are improving the teaching and learning environment by automating teachers' routine tasks such as grading, content creation, and administrative work.[32] In Rwanda, more than 75 per cent of stakeholders in a secondary school case study reported improvements in student engagement, academic performance, and operational efficiency through the use of real-time insights and automation of repetitive processes.[33]

LEVERAGING CRITICAL MINERALS ENDOWMENT

Frontier technologies such as digital traceability, blockchain, and biometrics are reshaping Africa's mining sector, especially in areas with complex supply chains and considerable informal artisanal mining. These tools support key policies on formalizing artisanal mining and responsible sourcing by improving traceability, worker rights, and environmental standards. For example, pilot projects in the Democratic Republic of the Congo use smartphone apps, digital ledgers, and biometric systems to track minerals such as cobalt (box 5.2). These technological advances not only enhance mining operations but also align with key African Union strategies, including the Africa Mining Vision and the African Green Minerals Strategy. As a result, adopting frontier technologies is central to Africa's pursuit of becoming a global leader in ethical and sustainable mineral production.

Box 5.2 Traceability technology for artisanal cobalt in the Democratic Republic of the Congo

In a series of pilot responsible sourcing and traceability initiatives across artisanal cobalt sites in eastern Democratic Republic of the Congo, nongovernmental organizations, a few forward-looking processors, and donor programmes introduced a packaged frontier technology solution: a smartphone app for site registration with digital ledgers (blockchain or tamper-evident databases) to record transactions and simple biometric ID and QR codes on metal batches. The system linked miners, cooperatives, local traders, and refiners (who consent), creating a verifiable paperless chain of custody from pit to plant. It reached thousands of miners during the evaluation period.[1]

The pilots produced measurable site-level productivity and income gains for participating miners: evaluation data from the Mutoshi pilot found higher output per worker during the project and reported higher monthly earnings for some women (about $34 a month on average for many, with some moving into roles paying $100 month).[2] Programme monitoring by Better Mining and partners documented extensive engagement.[3] Better Mining covered roughly 55,000 miners, monitored about 20 per cent of accessible artisanal cobalt sites in the region, and trained and provided technical support to hundreds of local stakeholders in 2021.

The pilots also enhanced transparency in transactions and offtake. Mutoshi and related offtake arrangements exhibited greater price transparency and buyer–cooperative relationships. But these arrangements did not insulate miners from broader global price shocks.[4]

Programmes created trained local roles (monitors, cooperative staff, and trainees) and enhanced skills and institutional capacity at the site level. Still, available reports do not provide a consolidated, sector-wide tally of new formal jobs (such as data clerks or logistics coordinators) directly attributable to traceability technology alone.[5]

The pilot outcomes align with the Africa Mining Vision goals (formalizing artisanal mining, local value capture, and governance) and with the African Green Minerals Strategy intent to produce critical minerals under higher social and environmental standards, while illustrating that scale, sustained finance, and long-term buyer commitments are required to convert pilot gains into durable, economy-wide impacts.[6]

1. RCS Global 2021.
2. Silva et al. 2019.
3. RCS Global 2021.
4. Hotter 2023.
5. RCS Global 2021.
6. African Union 2009, 2025.

INCREASING INTEREST IN NUCLEAR ENERGY

Small modular reactors represent a new generation of nuclear technology that advances access and productivity. With capacities under 300 megawatt electric per unit, these compact facilities can serve decentralized or off-grid applications without the massive infrastructure investment associated with conventional nuclear plants.[34] Their modular design enables incremental capacity expansion, aligning with Africa's growing yet distributed energy demands. Additionally, their stable baseload complements renewable generation. Thirteen African countries—Algeria, Ethiopia, Ghana, Kenya, Morocco, Namibia, Niger, Nigeria, Rwanda, Senegal, Tunisia, Uganda, and Zambia—are eyeing nuclear technology integration. In a high-case scenario, nuclear capacity could triple by 2030 and increase 10-fold by 2050, requiring more than $100 billion.[35] To integrate nuclear energy into the energy mix, African countries have to address challenges related to human capacity, industrial capabilities, financing resources, appropriate regulations, and supporting infrastructure, including infrastructure for waste disposal.

CREATING JOBS

Frontier technologies and generative AI technologies such as ChatGPT and Copilot represent a major shift in AI accessibility and utility. Unlike earlier breakthroughs confined to specialist domains, these tools enable users to perform both routine tasks, such as organizing data, and complex creative outputs, such as creating text, art, and music. Generative AI offers greater potential for enhancing productivity by augmenting human labour rather than replacing it, particularly in low- and middle-income countries.[36] While AI may displace 92 million jobs globally, it is also projected to create a remarkable 170 million new jobs, a net gain of 78 million—providing compelling support for AI's impact on job creation.[37] Frontier technologies thus operate not only as labour-saving tools but also as catalysts for entrepreneurship, innovation, trade expansion, and new forms of employment.

Chapter 2 provides empirical evidence that places these labour market effects in a dynamic perspective. In particular, the skills pillar exhibits a short-run negative effect on productivity before turning strongly positive in the medium term. This pattern is consistent with the presence of training, reallocation, and adjustment costs that initially dominate, even when long-run returns to skills and technology adoption are substantial. In labour market terms, this implies that job displacement and mismatch risks are most acute during the early transition phases—especially in economies with large informal sectors and limited reskilling systems—rather than being permanent outcomes of technological change.

The policy implication is that labour market responses to frontier technologies must be designed as transition policies, not just as long-term human capital investment. Sequencing matters. Rapid technology diffusion without parallel investment in skills systems, active labour market policies, and social protection can widen inequality and deepen skills mismatches. By contrast, sustained investment in skills development eventually raises productivity and supports job creation as new technologies are absorbed, adapted, and scaled across firms and sectors.

At the same time, AI's impact on labour markets depends not only on the pace of technology adoption but also on non-technological factors, including the relative costs of capital and labour, prevailing economic structures (including the flexibility of labour and product markets), and societal acceptance of new technologies and their applications. These factors can either amplify or mitigate AI's effects, resulting in vastly different outcomes across sectors

© Adobe Stock

and countries.[38] The global digital revolution and advances in frontier technologies require an adaptive and digital skilled workforce. Africa has the most youthful population of any region in the world, with a median age of 19, compared with 32 in Asia and in Latin America, 33 in Oceania, 39 in North America, and 42 in Europe.[39] This provides opportunities to train adaptive, creative, and innovative youth who also consume digital and innovative technologies, creating a market scope. The youth could be supported in leveraging frontier technologies and engaging in entrepreneurship through targeted training, innovation labs and innovation funds to facilitate access to finance, and other measures.

The ECA Alliance for Entrepreneurial Universities in Africa addresses youth and graduate unemployment by bridging gaps between academia, research, and industry. It fosters partnerships among universities, policymakers, and the private sector to update curricula, encourage entrepreneurship, and provide practical skills training through collaborative projects, internships, and mentorships. It also establishes innovation labs and startup incubators within universities to turn academic research into market-ready solutions and advocates for innovation funding to support young entrepreneurs. The initiative aims to produce digitally skilled graduates capable of leveraging frontier technologies and driving sustainable economic growth in Africa. The primary goal of implementing new workplace technologies is to enhance productivity and competitiveness. This is frequently accomplished by replacing human labour with machinery or software, enabling automated execution of tasks formerly performed by people. Classic examples include the tractor, the combine harvester, the forklift, and desktop publishing software, all of which have streamlined operations and reduced the need for manual effort.[40] Understanding AI's potential productivity impact on different sectors can help in identifying areas of human labour likely to be affected. Generative AI could unlock $61–$103 billion in economic value across Africa.[41] In South Africa alone, productivity gains from generative AI are estimated to contribute approximately 0.5 percentage points to GDP growth through automation.[42] Furthermore, demand for digital skills in Africa (excluding North Africa) is expected to grow faster than in other global markets, with an estimated 230 million digital jobs expected in the region by 2030.[43]

Retail and wholesale trade is the sector in Africa with the highest potential for AI and frontier technology–related productivity gains and subsequent labour impacts.

The effect of AI on jobs in Africa will be felt across multiple sectors, including retail trade, telecommunications, consumer packaged goods, mining, heavy industry and energy, and banking and financial services, given their potential for driving unrealized economic value in relation to generative AI.

Retail and wholesale trade is the sector in Africa with the highest potential for AI and frontier technology–related productivity gains and subsequent labour impacts. In 2020, Africa had the second highest number of people working in the sector globally (64.2 million). The sector accounts for 13.9 per cent of the continent's total employment, including 18.8 per cent of female employment and 10.1 per cent of male employment.[44] Women dominate the sector's employment, accounting for 58 per cent of total employment. Excluding North Africa from these figures paints an even starker picture, with women accounting for 63 per cent of total employment.[45]

Taking advantage of the continent's comparative advantage in herbal medicine

The exceptional depth of Africa's biodiversity and resilient indigenous knowledge system constitute a major comparative advantage. Fusing these assets with the growing capacity in frontier technologies will expose wealth in Africa's herbal medicine sector. The continent is home to about a quarter of the world's plant species, many of which have been studied only to the level of extracts. This untapped biological wealth can be integrated with AI and bioinformatics for compound screening, genomics, and metabolomics for target identification, blockchain for traceability and intellectual property protection, and advanced bioprocessing for scalable production. When this happens, Africa can move from being a raw material supplier to a global hub in phytomedicine. If supported by global institutions such as the United Nations

to digitize traditional knowledge, apply data-driven validation, and align with global regulatory science, Africa is uniquely positioned to lead a new frontier where ancestral herbal wisdom is transformed into evidence-based technology-enabled therapeutics for global health.

HARNESSING FRONTIER TECHNOLOGIES FOR THE SUSTAINABLE DEVELOPMENT GOALS

In recent years, frontier technologies have contributed to achieving the Sustainable Development Goals across several sectors (table 5.2).[46] By sustaining the current momentum of adopting frontier technologies and addressing the gaps in policies, capacity, and financing, Africa can close the Sustainable Development Goals achievement gaps more quickly and become a global case study for inclusive and sustainable adoption of frontier technologies. The leap from mobile-first to AI-driven, equitable digital economies is already under way, and how Africa manages this transition will determine whether the transformative promise of frontier technologies becomes a reality for all, leaving no one behind.

Africa has made progress in 12 of the 17 Sustainable Development Goals, but the pace remains too slow to meet the 2030 targets. Of 144 measurable targets, only about 10 are on track, more than 100 require accelerated action, and nearly 30 are moving in the wrong direction.[47] Frontier technologies therefore present one of the most powerful opportunities to fast-track progress and bridge this gap.

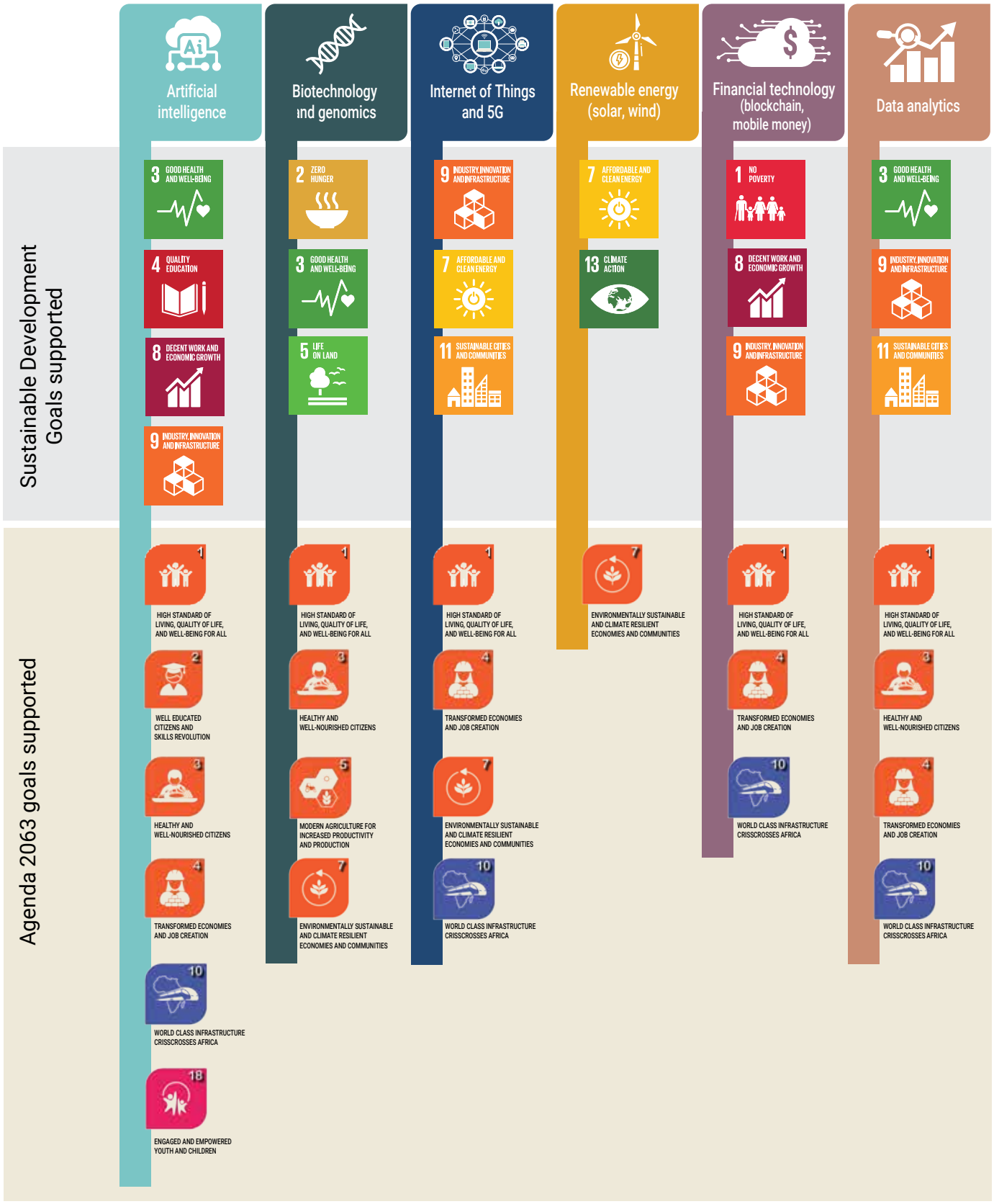
Digital and frontier technologies such as AI, IoT, big data, and biotechnology can positively influence up to 128 of the 169 SDG targets.[48] When guided by inclusive governance and sound policies, these technologies can drive progress across health, education, agriculture, and climate action while reducing inequalities both within and between countries.[49]

The continent's transition from a mobile-first to an AI-enabled, data-driven economy offers a unique chance to leapfrog traditional barriers and build digital ecosystems that are equitable and people centred.

Technology's impact is strongest when aligned with national development priorities. Digital innovation and better data governance directly improve productivity and institutional efficiency across Africa's key sectors.[50] AI and frontier technologies can also accelerate Sustainable Development Goal outcomes in developing economies when supported by inclusive, gender-responsive approaches.[51]

If Africa sustains its momentum in adopting new technologies while addressing the remaining policy, financing, and capacity gaps, it can narrow the Sustainable Development Goal achievement gap by 2030. Frontier technologies should be seen as tools to advance inclusive growth, environmental sustainability, and social equity—not as ends in themselves. The continent's transition from a mobile-first to an AI-enabled, data-driven economy offers a unique chance to leapfrog traditional barriers and build digital ecosystems that are equitable and people centred. How Africa governs this transformation will determine whether the promise of frontier technologies becomes a lived reality for all, ensuring that no one is left behind on the path to achieving the Sustainable Development Goals.

Table 5.2 Frontier technology alignment with the Sustainable Development Goals and Agenda 2063



Note: This table is only illustrative and does not display an exhaustive alignment of frontier technologies with the Sustainable Development Goals and Agenda 2063 goals.

Source: ECA elaboration.

CHALLENGES AND RISKS IN ADOPTING FRONTIER TECHNOLOGIES IN AFRICA

While frontier and emerging technologies hold great promise for Africa, they also bring a set of risks, challenges, and open questions that must be addressed to ensure the technology is used responsibly and equitably. Most of these have been touched upon in sector discussions; here we consolidate the key cross-cutting issues.

The Chapter 2 results suggest a practical prioritisation of these constraints. The strongest and most persistent productivity effects come from skills development and industrial activity, implying that weaknesses in human capital systems and productive capabilities represent the most binding constraints on sustained technology dividends. ICT deficits remain important but appear to operate largely as an enabling condition rather than the main driver of durable productivity gains. By contrast, weak or volatile effects for R&D and finance suggest that, in many settings, these channels are constrained by long gestation periods (R&D) and misallocation (finance) and therefore require complementary reforms to become effective.

CHALLENGES

Infrastructure deficit

Many regions in Africa experience limited access to reliable electricity, broadband, and computing resources, which restricts the adoption of frontier technologies such as AI systems, particularly those relying on cloud computing or big data. Power interruptions and high internet costs or slow speeds can disrupt technology services—for instance, an AI diagnostic tool cannot function without consistent power or network connectivity. In addition, the continent faces considerable challenges in energy transition, as the shift from traditional energy sources to more sustainable and renewable options remains slow and uneven. One key challenge in Africa is the wide disparity in internet connectivity between rural and urban areas. The limited access to technology infrastructure, including digital devices, remains a major barrier to adopting frontier technologies for innovation. This, in turn, affects access to education and decent jobs especially for youth, underserved groups, and the rural population.

Energy and water consumption

Another key barrier to adopting frontier technologies such as building data centres in Africa is high energy and water consumption. Data centres use about 415 terawatt-hours, or 1.5 per cent of global electricity, and a single 1 megawatt site can consume up to 25.5 million litres of water a year for cooling—equal to what around 300,000 people need each day. This strains local utilities and raises costs, especially where renewable infrastructure is limited, while worsening water scarcity. These challenges underscore the need for investment in sustainable energy and water solutions to enable Africa's digital growth. For Africa to seize the growth and transformation opportunities embedded in frontier technologies and growing global data centres, a detailed assessment of energy and water requirements, investment requirements, and potential regional hubs is recommended.

Data challenges

Data availability and quality. Frontier technologies rely on access to relevant, high-quality, and standardized data. But Africa continues to experience challenges with data scarcity and fragmentation. In healthcare, language processing, financial services, environment, and agriculture, many local datasets are limited or incomplete. For instance, there is a notable shortage of medical image collections in African hospitals, annotated speech data for diverse African languages, and reliable records for agricultural markets. This limited data availability hampers the development of tailored technological solutions and restricts innovation across the continent.

Data value chains. Efficient data movement across collection, storage, processing, analysis, access, and use drives innovation and growth. But in Africa, gaps persist in official statistics, especially for informal economic and social activities. National statistical offices are improving administrative data, but challenges with integration, fragmented systems, and quality issues remain in health, agriculture, education, and labour markets.

Limited access to high-performance computing and expensive cloud services hinders local data storage, processing, and advanced analytics. While the Statistical Data and Metadata eXchange has improved accessibility, siloed data across agencies and sectors remains a barrier to integration and innovation. Clear data-sharing policies and transparent markets are essential for allowing collaboration, protecting privacy, and enabling African businesses to leverage valuable datasets—particularly those owned by private firms.

Data and other operating costs. Affordable, reliable access to large datasets is vital for AI, IoT, big data analytics, and machine learning, yet high data costs limit startups and researchers in Africa. Factors such as internet pricing, infrastructure, and regulations create barriers, with Africa (excluding North Africa) facing an average cost per gigabyte 1.3 times the global rate in 2023. For many African businesses, internet expenses are unsustainable and restrict data use, resulting in the region consuming the least data globally. Between 2019 and 2024, monthly broadband traffic in Africa increased from 77 gigabytes per subscription to 159, compared with a global jump from 141 to 311.

Digital skills and capacity gaps

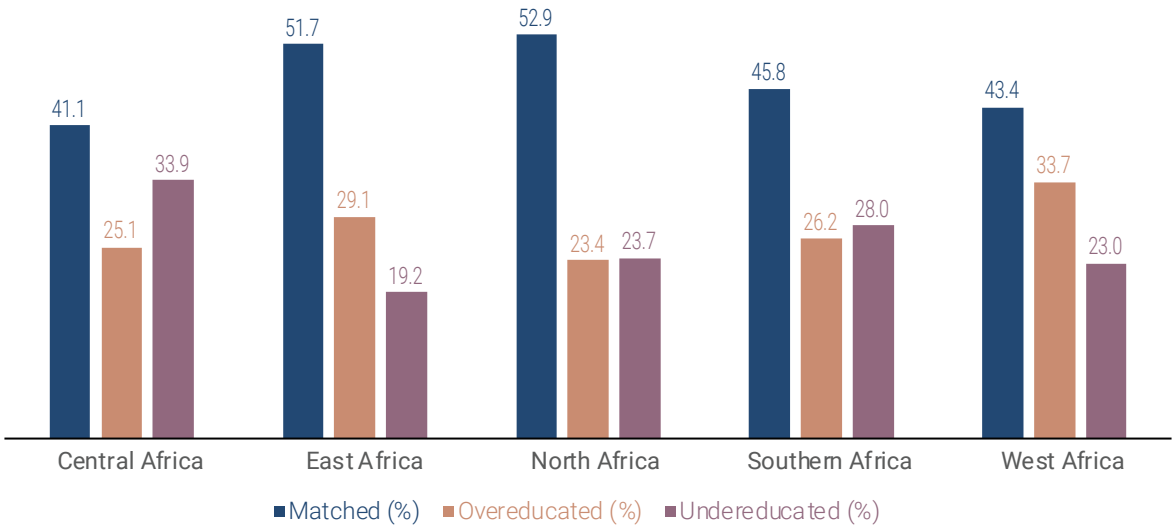
Across Africa, the shortage of expertise in advanced fields such as AI, IoT, and blockchain limits the capacity of public and private institutions to manage and analyse data systematically and harness the power of data to support frontier technologies. Africans account for only 1 per cent of the global AI talent pool.[52] This strikingly low figure highlights both the underrepresentation and the substantial skills gap on the continent. Few universities offer specialized degrees in these disciplines, and many of the continent's most promising researchers and engineers pursue careers abroad, attracted by better resources and opportunities. This brain drain means that governments and businesses often depend on foreign experts or prepackaged technology solutions, which can hinder the development of locally tailored innovations. Building local capacity is essential to ensure that Africa's adoption of frontier technologies is sustainable and inclusive. To tackle these challenges, a variety of initiatives have emerged. Regional workshops such as Deep Learning Indaba bring together students from across Africa to learn directly from international experts. Major technology companies—including Google and IBM—are launching training and scholarship programmes focused on digital skills and AI development. Ethiopia and Nigeria are exploring integrating frontier technology education into school curricula to create a pipeline of future talent.

Skills mismatch and gender gap

Advanced skills and capabilities are crucial for harnessing the full potential of frontier technologies in Africa. While these technologies offer the promise of more inclusive economies and societies and address environmental concerns, they also render some jobs obsolete. The quality of education and the mismatch between the skills the education system provides and the evolving needs of labour markets are challenges in Africa. Digital skills are increasingly essential, but only 50 per cent of African countries have integrated computer skills into school curricula, compared with 85 per cent in other world regions.[53] Similarly, education systems in Africa fail to prepare students with the agriculture and agro-processing skills required for rural development. This mismatch undermines education's potential to empower the youth population to support Africa's development and meet future labour market needs.

Between 2017 and 2021, the average share of matched graduates[54] shows persistent skill mismatches across African subregions, with none exceeding 53 per cent proper alignment (figure 5.1). North and East Africa perform better, yet nearly half of graduates in those subregions remain mismatched, indicating weak labour market absorption. Southern Africa shows both high overeducation and undereducation, suggesting labour market segmentation and credential inflation. Central Africa registered the lowest match rate and highest undereducation, reflecting inefficiency in graduate employment outcomes.

Figure 5.1 Education and labour market alignment (%)

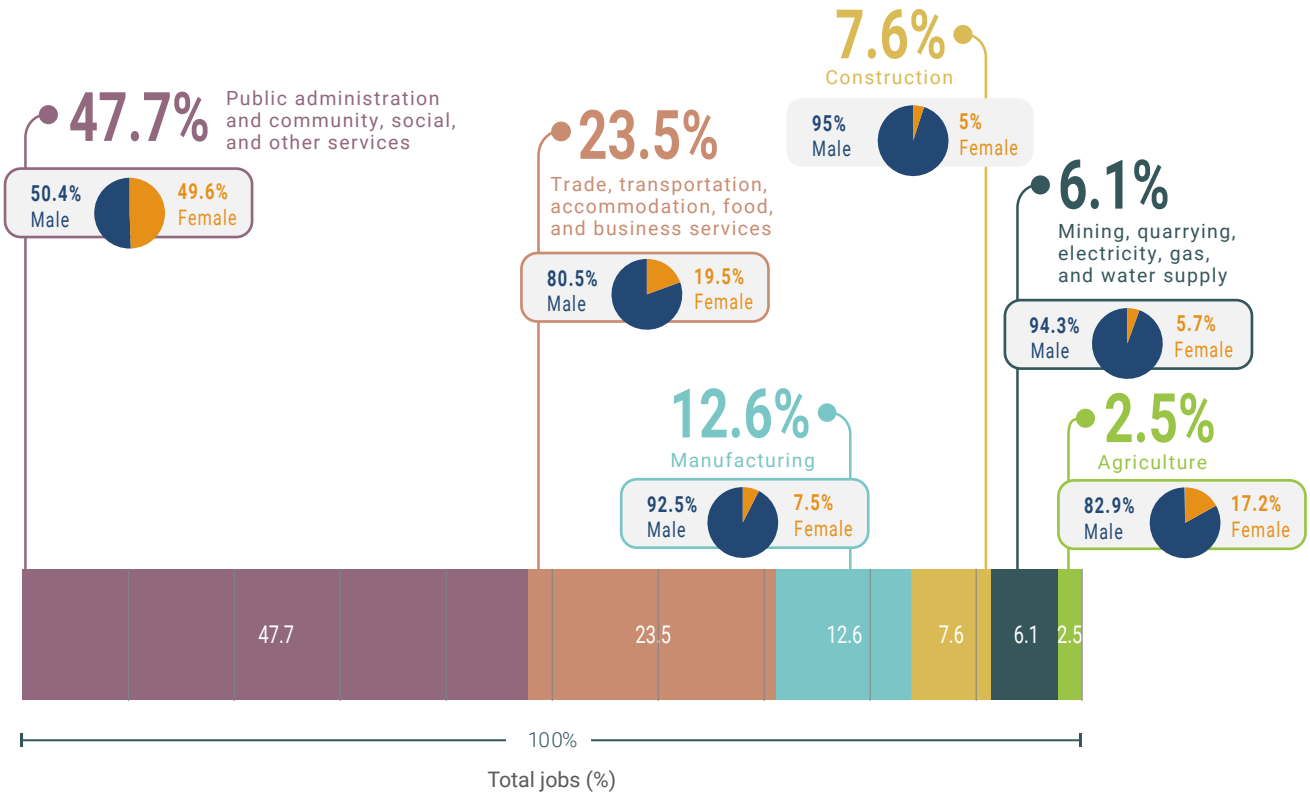


Source: ECA elaboration based on ILO (2025a).

Science, technology, engineering, and mathematics occupations and the gender gap

Based on 2022 data from 16 African countries, public administration and community, social, and other services host the highest number of STEM occupations (47.7 per cent), followed by trade, transportation, accommodation, and food and business services (23.5 per cent) and manufacturing (12.6 per cent) (figure 5.2).[55] Across six sectors, men accounted for about 69.7 per cent of total STEM employment, women for 30.3 per cent . This reflects a persistent gender employment gap in STEM occupations, with the imbalance most pronounced in industrial sectors, while service-oriented sectors show greater gender inclusion, with women accounting for 49.6 per cent of employment and men for 50.4 per cent.

Figure 5.2 Employment in science, technology, engineering, and mathematics occupations across 16 African countries, by gender, 2022 (%)



Source: ECA elaboration based on ILO (2025a).

In Botswana and Egypt, the percentage of female employees in public administration and community, social, and others services is higher than that of male employees, (54.0 per cent versus 46.0 per cent in Botswana and 55.8 per cent versus 44.2 per cent in Egypt between 2021 to 2023). But in Rwanda and Zambia, the gender imbalance is wider, even in the public administration and services sector (38.5 per cent versus 61.5 per cent in Rwanda and 33.1 per cent versus 66.9 per cent in Zambia). Closing this gender and overall employment gap in STEM-intensive sectors could greatly increase Africa's workforce productivity and economic growth.

Governance and regulatory preparedness

Adopting frontier technologies in Africa depends on effective governance. While initiatives such as the African Union's Continental Artificial Intelligence Strategy and national AI policies are a step forward, regulators must balance innovation with safeguards. Comprehensive and transparent frameworks are required to ensure responsible management, broad access, and equitable distribution of benefits while mitigating risks. The challenge is twofold: a regulatory framework that is too loose may enable harmful practices or unchecked risks, whereas overly restrictive rules could stifle the transformative potential of these technologies. The rapid evolution of frontier technologies often outpaces traditional policymaking, making it difficult for regulations to stay current. To navigate this, several African countries have begun to experiment with regulatory sandboxes—controlled environments where new technology solutions can be tested under the watchful eye of regulators. For example, Kenya and Rwanda have successfully piloted sandboxes in the financial technology sector, and similar models could be adapted to oversee and innovate in AI-driven healthcare, smart agriculture, or digital identity systems. Another pressing concern is the fragmentation of standards and policies across the continent.

The impacts of generative artificial intelligence on African jobs

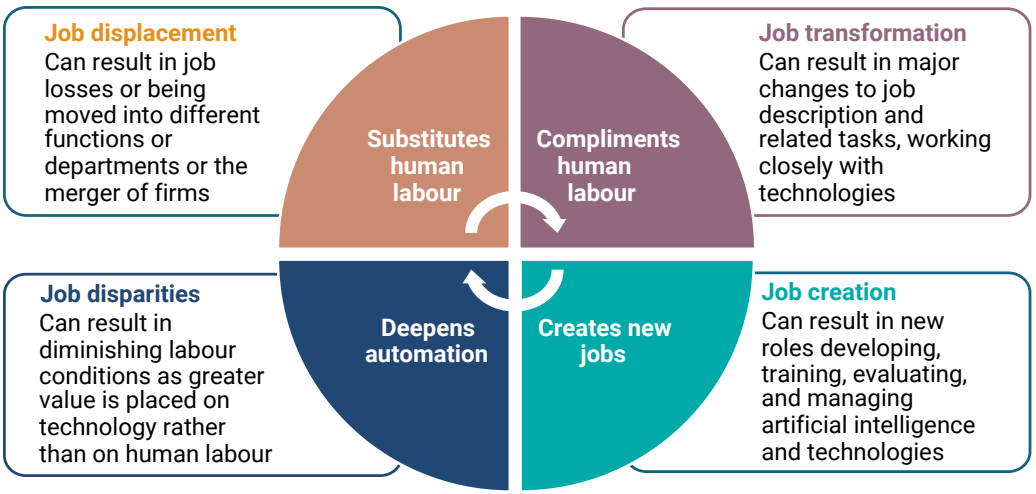
The widespread adoption of generative AI has sparked public interest and debate over societal and economic impacts, often without sufficient analytical frameworks. For policymakers, researchers, industry leaders, and workers, understanding these shifts is critical to anticipating implications for labour markets, innovation, and governance. Overall, generative AI offers greater potential for augmenting human labour than replacing it, particularly in low- and middle-income countries.[56] In the short term, developed countries are generally more likely than developing countries to experience rapid labour market adjustments and rising wage inequality due to AI. Generative AI will have a major impact across all sectors of industry.[57] But for developing countries, labour market impacts from rapid technological change depend on both domestic innovation and technological advances abroad that reshape global production and trade patterns.[58]

In the context of AI, productivity and human labour are related in four important ways, where productivity gains achieved through AI affect human labour dynamics, often simultaneously, having both positive and negative implications (figure 5.3).[59] To understand the impacts on Africa's labour dynamics,

In the context of AI, productivity and human labour are related in four important ways, where productivity gains achieved through AI affect human labour dynamics, often simultaneously, having both positive and negative implications.

it is thus also necessary to identify how African countries are poised to benefit from such productivity gains. Over the long term, technological progress has generally reinforced—rather than diminished—the overall demand for human labour. Nevertheless, the disruptive impacts of new technologies cannot be overlooked, as emphasized in chapter 2. Technology-driven job losses tend to occur quickly, whereas creating new employment opportunities often requires time. Moreover, new jobs frequently differ from the ones displaced in terms of industry, required skills, and geographic location, increasing the risk of worker displacement and presenting challenges for policymakers tasked with managing workforce transitions.[60]

Figure 5.3 The impact of artificial intelligence on jobs



Source: Adapted from UNCTAD (2025c).

Labour costs play a central role in a firm's decisionmaking on the potential benefits and productivity gains from automation. This explains why developing countries with abundant low-cost labour have experienced limited impacts from automation. The generally low wages in many developing countries—particularly in the services sector—are likely to continue mitigating the incentives for automation and reducing the risk of job displacement in the near future.[61] Furthermore, to prevent deskilling and reduce the risk of brain drain to developed countries, developing countries must enhance labour market opportunities, offer continuous upskilling and reskilling to leverage new opportunities, and establish clear career development pathways.[62] Promoting regional mobility programmes—such as the African Union's Digital Skills Agenda and human resource mobility under the AfCFTA—can also mitigate deskilling. These initiatives enable workers to access training, certification, and employment opportunities across borders, facilitating the sharing of best practices and fostering a more resilient and adaptable workforce. By supporting regional collaboration on digital skills development and harmonizing qualifications, countries can better retain talent within the continent and ensure that African workers remain competitive in the evolving digital economy.

Generative AI has been described as a double-edged sword for Africans. On the one hand, it offers the potential to expand access to education, training, and skills development, enabling African youth and others to advance. But on the other hand, disruptions in labour markets, together with existing rigidities, may exacerbate unemployment and reinforce or even amplify existing social and economic inequalities across the continent.[63]

The challenges matrix in table 5.3 classifies challenges of frontier technology adoption by the time horizon of policy response. Challenges requiring immediate policy attention are those that can quickly block adoption, undermine trust, or generate fiscal and political risks if left unaddressed. Incremental challenges are best tackled through sustained programmes and institutional strengthening over several years. Long-term structural challenges reflect deep-seated constraints such as infrastructure and energy systems that require multi-year investment and coordination. This matrix can help policymakers prioritize actions, sequence interventions, and align responses with institutional capacity.

Table 5.3 Challenges in adopting frontier technology in Africa

Challenge	Policy priority tier	Why this tier applies	Indicative policy focus
Governance and regulatory preparedness	Immediate policy attention	Unclear rules undermine trust, stall investment, and fragment implementation.	Minimum viable regulation, mandate clarity, sandboxes, and interim guidance.
Data availability and quality	Immediate policy attention	Weak data break interoperability, targeting, and system credibility.	Priority datasets, data standards, and interoperability protocols.
Data and other operating costs	Immediate policy attention	Unbudgeted recurrent costs cause post-pilot collapse and fiscal stress.	Lifecycle costing, operations and maintenance budgeting, procurement reform.
The impact of generative artificial intelligence on jobs	Immediate policy attention	The impact can be job creation, job transformation, job displacement, or job disparities.	Promoting entrepreneurship, reskilling, redeployment, and inclusion policies.
Science, technology, engineering, and mathematics (STEM) occupations and the gender gap	Incremental action	The gender gap results in skills shortages, slower innovation, wider income inequality, and exclusion.	Inclusive STEM education, mentorship, and targeted scholarships for girls and women.
Digital skills and capacity gaps	Incremental action	Skills pipelines and institutional capacity take time to build.	Civil service upskilling, small and medium enterprise extension services.
Skills mismatch and gender gap	Incremental action	Mismatch reflects labour market and access barriers.	Demand-driven training, apprenticeships, and targeted gender support.
Infrastructure deficit	Long-term structural	Infrastructure development requires large capital investment and coordination.	Broadband expansion, power, and logistics investment.
Energy and water consumption	Long-term structural change	Usage depends on the energy mix, efficiency, and water governance.	Efficiency standards, renewables, grid upgrades.

Source: ECA elaboration.

RISKS

Data governance: privacy, sovereignty, and protection

Managing data growth in the digital era requires effective national and regional governance frameworks. While some African regions have implemented data protection and cybersecurity laws, comprehensive data governance legislation remains limited in most countries. Many lack national cybersecurity strategies, incident response teams, and critical infrastructure protections. This heightens vulnerability to cybercrime, cyber espionage, and systemic digital disruptions, identified as among Africa's top emerging risks in recent regional assessments.[64] This gap can result in data availability, access, and management not being consistently addressed, leading to fragmented approaches and challenges in responding to emerging risks. Advancing global technology, including AI, introduces ethical considerations and necessitates that governments balance citizen protection and sovereignty with efforts to develop data systems that are inclusive, equitable, and reliable. These issues can affect economic development, contribute to inequality, and create barriers for local startups seeking access to vital datasets, which may lead to greater reliance on foreign platforms and resource outflows.

In response, the African Union Data Policy Framework, launched in 2022, aims to treat data as a strategic asset by promoting common standards and governance mechanisms, fostering trust, ensuring privacy and security, facilitating cross-border data flows, and supporting data use for innovation, economic change, and broader policy development. In this regard, ECA helps Member States mitigate risks related to data breaches, regulatory uncertainty, and exclusion, while enabling innovation, cross-border data flows, and regional integration. This integrated approach ensures that technological development in Africa supports trust, accountability, and inclusive economic transformation rather than reinforcing existing digital and technological divides. For instance, in partnership with the GIZ Office of the African Union, ECA is taking a leading role in shaping the continent's data future by spearheading the development of comprehensive national data governance strategies that are in line with the African Union data governance framework in several countries, including Burundi, the Democratic Republic of the Congo, Mozambique, and the United Republic of Tanzania.[65] These efforts are complemented by capacity-building workshops, technical assistance, and knowledge-sharing platforms, all geared towards empowering Member States to manage, protect, and leverage their data assets.

Absence of open, usable data

Developers in AI, machine learning, and IoT often depend on imported datasets, which may not accurately reflect African conditions and can result in less effective solutions. Collecting new local data is possible but generally requires substantial time and resources. The quality of available data also varies, with public statistics sometimes outdated or incomplete.

Financial and investment risks

Limited access to capital, high interest rates, and underdeveloped venture capital ecosystems restrict the ability of local startups and established firms to invest in cutting-edge infrastructure and innovation. Investors may be deterred by perceived political and regulatory uncertainties, currency fluctuations, and the high costs of technology deployment on the continent. Furthermore, the absence of tailored financial products and risk mitigation instruments makes it challenging for both public and private sector actors to efficiently allocate resources towards long-term technological projects. As a result, many African countries remain dependent on foreign investment and donor funding, which can be unpredictable and subject to shifting global priorities, ultimately hindering sustainable growth and the scaling of digital solutions. In this context, public-private partnerships are critical for mobilizing resources and fostering collaboration among government, the private sector, and other stakeholders for developing and deploying selected technologies. With an enabling environment for innovation and investment, public-private partnerships can bridge the financing gap by pooling resources and sharing risks, while leveraging the strengths and expertise of each sector.

Storing data outside the continent

Africa's data are often kept in paper or isolated electronic formats, hindering access due to poor infrastructure, limited expertise, and low investment. Africa's data centre capacity (307 megawatts) is less

than 2 per cent of the global total, and the continent will need at least 1,200 megawatts more by 2030.[66] Relying on overseas servers increases costs, latency, and risks to security, privacy, and sovereignty, particularly for sensitive data such as medical, financial, and security data.

Over-dependence on foreign technology

Dependence on imported hardware, software, cloud infrastructure, and specialized components exposes African economies to supply shocks, price volatility, and technology lock-in.[67] Limited domestic manufacturing and research and development capacity further restrict opportunities for local value addition.

Few internet service providers

The limited number of internet service providers in Africa leads to higher costs and less competition. Data markets are fragmented and informal, and data centre infrastructure is thinly spread, with nearly half the continent's 211 data centres located in just four countries. As a result, prices for space, power, and connectivity are higher than in more competitive markets. Building a 1 megawatt data centre is much more expensive in some African countries: $15 million in Nigeria in 2024, compared with the global average of $10 million, ranking the country seventh in the world.[68] Additionally, markets with fewer mobile data operators pay substantially more per gigabyte than those with greater competition.

Power instability

Power instability raises operating costs because businesses need backup systems and extra security, which increases service prices. The 2025 World Bank Enterprise Surveys indicate that 51.1 per cent of firms in Sub-Saharan Africa own or share a generator and go about 14 hours a month without electricity, driving additional spending on fuel, maintenance, and backup equipment.[69] Mobile operators in South Africa spent R174 million ($9.5 million) on backup batteries and R211 million ($11.5 million) on generators in 2024, and the electricity sector also reported R69 million ($3.8 million) in costs linked to infrastructure theft, stressing the issues of extra security costs around power equipment.[70]

Tax burdens and lack of incentives

Most digital equipment is imported and faces duties, taxes, currency issues, and expensive logistics, making it unaffordable for small businesses and public institutions. Additional taxes on information and communications technology further limit access. For example, Uganda's daily social media tax led to a loss of more than 2.5 million internet subscribers and a 25 per cent drop in mobile money transactions within months. Lack of skilled professionals further increases the cost of hiring and retaining expatriates. For instance, at a Kenyan telephony company, expatriate staff expenses represented 15.6 per cent of total employee pay and benefits for the year ending March 2024, despite a 17.7 percentage point drop from the previous year.[71]

Disruptive effects from new technologies

Job losses due to technology tend to occur quickly, while job creation often takes longer. And new roles associated with frontier technologies usually differ from those displaced in terms of industry, required skills, and location, thereby increasing the risk of job displacement and posing challenges for policymakers managing workforce transitions.[72] Labour market disruptions, combined with existing rigidities, can worsen unemployment and deepen or even magnify social and economic inequalities across the continent.[73]

Ethical and social risks

The rapid deployment of frontier and emerging technologies such as AI, IoT, and blockchain brings with it a unique set of ethical and social concerns. Issues such as access to digital tools, data privacy, cultural representation in AI systems, and the potential for reinforcing existing inequalities are particularly relevant in the African context. These advanced systems can unintentionally reinforce or even intensify existing biases and social inequalities if their design and implementation are not handled with care. For instance, facial recognition technologies, a hallmark of the latest AI advancements, have been shown to carry racial biases. Deploying these tools in Africa without proper localization and inclusive data training increases the risk of misidentification, which could lead to wrongful surveillance or arrests within certain communities. Predictive analytics in policing or hiring, powered by algorithms trained on biased

or incomplete data, might disproportionately impact marginalized groups or neighbourhoods—replicating and deepening historical injustices.

Trust and public awareness

Adopting frontier and emerging technologies across Africa hinges on public trust. Local communities that perceive innovations such as AI, IoT, or blockchain as opaque or imposed from outside may resist engaging with these tools—for instance, harbouring doubts about digital health diagnostics or declining to use smart agricultural platforms. Earning trust requires well-designed public awareness campaigns that make the technologies relatable, showcase real-world African success stories, and actively involve local communities in testing and shaping solutions. Transparency is essential.

The political economy of science, technology, and innovation funding

Political economy shapes science, technology, and innovation policies, meaning that the extent to which these policies can help African countries achieve their development aspirations is not straightforward. Science, technology, and innovation funding, who provides it, and what is funded are all choices that shape policymaking and how systems develop, with consequences for who wins and who loses and whether a country's development objectives are achieved.[74] Donors and foreign universities influence research agendas in some instances, meaning that research activities are not always aligned with government development priorities.[75] There is therefore a risk that science, technology, and innovation in Africa may not be autonomous in funding and direction. Science diplomacy could be used to foster strategic partnerships to implement African countries' research priorities and build trust in science. It could shape the global research agenda with African priorities.

The risks matrix in table 5.4 organizes risks associated with frontier technologies by potential impact, reversibility, and the timeframe over which policy can effectively mitigate them. Immediate risks are those that can cause rapid loss of trust, legal exposure, or financial harm and therefore require early safeguards. Incremental risks can be reduced progressively through capability building, governance improvements, and market development. Long-term structural risks arise from foundational infrastructure, market structure, or sovereignty considerations that cannot be resolved quickly. The matrix supports proactive risk management by directing early attention to high-impact, hard-to-reverse risks.

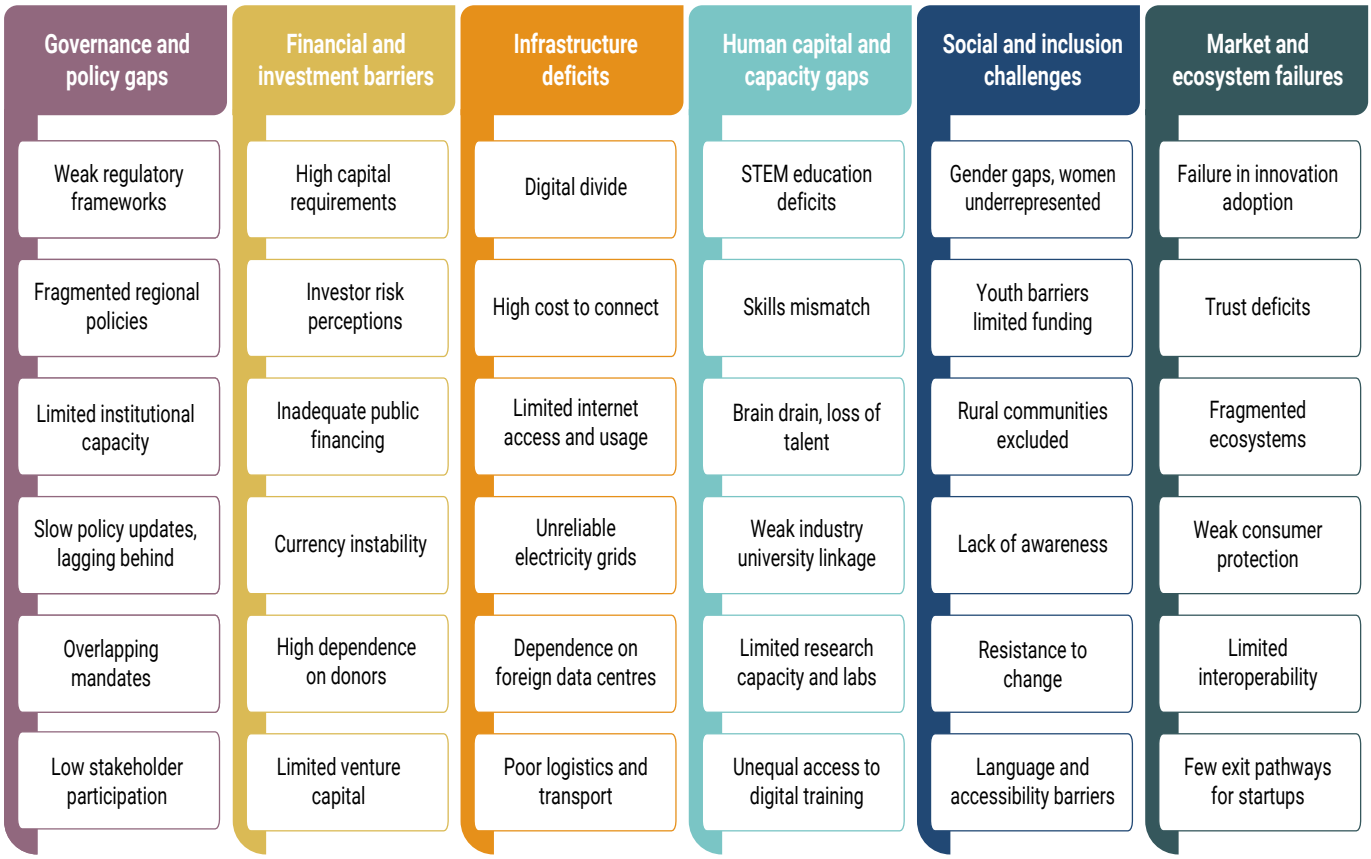
Table 5.4 Risks in adopting frontier technologies in Africa

Risk	Policy priority tier	Why this tier applies	Indicative risk management focus
Data governance: privacy, sovereignty, and protection	Immediate policy attention	Weak protections and enforcement rapidly undermine trust, adoption, and political legitimacy.	Baseline data protection and cybersecurity regimes, enforcement capacity, and breach response.
Financial and investment risks	Immediate policy attention	High uncertainty and fiscal exposure can quickly stall initiatives or create hidden liabilities.	Lifecycle costing, value-for-money tests, staged financing, contingent liability management.
Ethical and social risks	Immediate policy attention	Bias, exclusion, and misuse can emerge early and erode legitimacy, even in pilots.	Ethical guidelines, impact assessments, auditability, and grievance redress.
Trust and public awareness	Immediate policy attention	Low trust and misinformation can sharply reduce uptake and increase resistance.	Transparency, risk communication, community engagement, and digital literacy.
Disruptive effects	Immediate policy attention	Disruptive effects include automating routine tasks, transforming skill demands, and creating new roles.	Proactive reskilling, adaptive education systems, and inclusive policies.
Absence of open, usable data	Incremental policy action	Open data ecosystems require sustained standards, stewardship, and quality improvement.	Priority datasets, open standards, data quality programmes, and trusted intermediaries.
Over-dependence on foreign technology	Incremental policy action	Reducing dependency requires capability building and procurement reform over time.	Open standards, modular procurement, local ecosystem development, and skills transfer.
The political economy of science, technology, and innovation funding	Incremental policy action	Funding continuity depends on coalitions and multi-cycle budget processes.	Multi-year science, technology, and innovation budgeting, independent grant governance, performance-based funding.
Storing data outside the continent	Long-term structural change	Local and regional hosting capacity depends on power, connectivity, and scale economics.	Regional data infrastructure strategy, local hosting incentives, resilience planning.
Few internet service providers	Long-term structural change	Market concentration and backbone investment change slowly and require structural reform.	Pro-competition regulation, open access infrastructure, licensing reform.
Power instability	Long-term structural change	Reliable power is foundational for frontier technologies and requires major infrastructure investment.	Grid reliability upgrades, distributed energy solutions, and standards for critical digital infrastructure.

Source: ECA elaboration.

This chapter reveals the multidimensional nature of the challenges and risks plaguing the adoption of frontier technologies for Africa's economic transformation. Based on the analysis in the chapter and this report in general, figure 5.4 groups the identified challenges and risks into six categories: governance and policy gaps, financial and investment barriers, infrastructure deficits, human capital and capacity gaps, social and inclusion challenges, and market and ecosystem failures.

Figure 5.4 Categorization of challenges and risks in harnessing data and adopting frontier technologies in Africa



STEM is science, technology, engineering, and mathematics.

Source: ECA elaboration.

CONCLUSION

This chapter presents an analysis of various approaches to adopting frontier technologies in Africa, highlighting both effective and less effective practices, as well as areas requiring further attention to support industrialization and structural transformation. The findings demonstrate that frontier technologies such as AI, IoT, blockchain, renewable energy solutions, and advanced robotics can support African economies in transitioning from dependence on raw commodity exports to higher-value production and services. For instance, integrating clean energy technologies is enabling more reliable and sustainable power supplies for industry and households, thus fostering new business models and rural electrification. Applying these advanced technologies has improved manufacturing processes, streamlined logistics, reduced operational costs, and brought greater transparency to trade, thereby strengthening the competitiveness of local industries and supporting inclusive economic growth.

But the experiences and analysis presented in this chapter outline effective and less effective approaches, along with areas that may need additional consideration. The findings reinforce the necessity of ongoing evaluation, flexible approaches, and adaptive policymaking as Africa implements technology for development. Drawing on the comprehensive review and the realities outlined in this chapter, chapter 6 presents a series of policy packages designed as actionable frameworks tailored to Africa's unique context, aiming to address the governance and policy gaps, financial and investment barriers, infrastructures deficits, human capital and capacity gaps, social and inclusion challenges, and market and ecosystem failures identified in this chapter. The policy packages also directly confront critical issues related to data, such as fragmented and informal data markets, limited data centre infrastructure, high connectivity and storage costs, and barriers to data access and use. Chapter 6 also outlines key priorities and practical forward-looking steps for stakeholders, providing a roadmap for translating the lessons learned into concrete strategies that will accelerate the continent's digital transformation and industrial advancement.

REFERENCES

Abdulai, A.-R., P. Tetteh Quarshie, E. Duncan, and E. Fraser. 2023. "Is Agricultural Digitization a Reality among Smallholder Farmers in Africa? Unpacking Farmers' Lived Realities of Engagement with Digital Tools and Services in Rural Northern Ghana." *Agriculture & Food Security* 12 (1): 11. https://doi.org/10.1186/s40066-023-00416-6.

Acemoglu, D., A. Manera, and P. Restrepo. 2020. "Does the US Tax Code Favor Automation?" Brookings Institution. https://www.brookings.edu/wp-content/uploads/2020/12/Acemoglu-FINAL-WEB.pdf?utm_source=chatgpt.com.

ACTS (African Centre for Technology Studies). 2024. *Application of AI in Education in Africa.* ACTS. https://ai4d.acts-net.org/wp-content/uploads/APPLICATION-OF-AI-IN-EDUCATION-IN-AFRICA.pdf.

AfDB (African Development Bank). 2025. "Digital Transformation Action Plan 2024–2028." AfDB, Abidjan. https://vcda.afdb.org/en/system/files/report/DTAP_Detailed%20Version.pdf.

Africa Arbitration. 2022. "Togo's Land Registry Now Fully Dematerialized." *Africa Arbitration*, November 21. https://africaarbitration.org/2022/11/21/togos-land-registry-now-fully-dematerialized/.

Africa Data Centres Association. 2024. "How Africa Can Leapfrog the World in Sustainable Digital Infrastructure Development." July 17. https://africadca.org/en/how-africa-can-leapfrog-the-world-in-sustainable-digital-infrastructure-development.

African Union. 2009. *Africa Mining Vision (AMV).* African Union, Addis Ababa. https://au.int/en/ti/amv/about.

African Union. 2025. *Africa's Green Minerals Strategy (AGMS).* African Union, Addis Ababa. https://au.int/en/documents/20250318/africas-green-minerals-strategy-agms.

AGRA (Alliance for a Green Revolution in Africa). 2020. *Lessons from Esoko's Ghana Pilot Project.* AGRA. https://agra.org/wp-content/uploads/2020/10/Esoko-m-Commerce-Ghana-Pilot-Project.pdf?utm_source=chatgpt.com.

Arab Republic of Egypt. 2023. "E-Government Service Portal—Home." Egyptian Government Services Portal. Accessed January 29, 2026. https://www.eta.gov.eg/en/home.

AUC (African Union Commission). 2020. *Digital Transformation Strategy for Africa (2020–2030).* African Union, Addis Ababa. https://au.int/sites/default/files/documents/38507-doc-DTS_for_Africa_2020-2030_English.pdf.

AUDA-NEPAD (African Union Development Agency–NEPAD). 2024. *AI and the Future of Work in Africa.* AUDA-NEPAD. https://www.nepad.org/publication/ai-and-future-of-work-africa-white-paper.

Bailey, B. 2025. "2,500 Ride-Hailing Apps Not Enough to Break Uber, Bolt Stronghold." TechCabal, March 20. https://techcabal.com/2025/03/20/ride-hailing-apps-that-have-failed/.

Basu, K., Z. Qureshi, and D. Rodrik. 2022. *An Inclusive Future: Technology, New Dynamics, and Policy Challenges.* Brookings Institution. https://www.brookings.edu/wp-content/uploads/2022/05/Inclusive-future_Technology-new-dynamics-policy-challenges.pdf.

BloombergNEF. 2024. *Energy Transition Factbook 2024.* BloombergNEF. https://assets.bbhub.io/professional/sites/24/Clean-Energy-Ministerial-Factbook-2024.pdf.

BMW Group. 2025. "BMW Group Plant Rosslyn." BMW Group, September 10. https://www.bmwgroup-werke.com/rosslyn/en.html.

Bosman, I. 2023. "Digital Identification and Biometrics in East Africa: Opportunities and Concerns." SAIIA (South African Institute of International Affairs), November 9. https://saiia.org.za/research/digital-identification-and-biometrics-in-east-africa-opportunities-and-concerns/.

Bouke, M. A., A. Abdullah, S. H. Alshatebi, H. El Atigh, and K. Cengiz. 2023. "African Union Convention on Cyber Security and Personal Data Protection: Challenges and Future Directions." *arXiv.* https://doi.org/10.48550/ARXIV.2307.01966.

Brynjolfsson, E., D. Rock, and C. Syverson. 2017. "Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics." NBER Working Paper 24001. National Bureau of Economic Research, Cambridge, MA. https://doi.org/10.3386/w24001.

Bullock, J. B., Y.-C. Chen, J. Himmelreich, V. M. Hudson, A. Korinek, M. M. Young, and B. Zhang, eds. 2024. *The Oxford Handbook of AI Governance.* 1st ed. Oxford University Press, Oxford. https://doi.org/10.1093/oxfordhb/9780197579329.001.0001.

Carroll, M. 2023. *Sex Gaps in Education in England.* Cambridge Assessment. https://www.cambridgeassessment.org.uk/Images/698454-sex-gaps-in-education-in-england.pdf.

Cazzaniga, M., F. Jaumotte, L. Li, G. Melina, A. J. Panton, C. Pizzinelli, E. J. Rockall, and M. M. Tavares. 2024. "Gen-AI: Artificial Intelligence and the Future of Work." IMF Staff Discussion Note 2024/001. International Monetary Fund, Washington, DC. https://doi.org/10.5089/9798400262548.006.

Ceselli, V. 2022. "Embedded Intelligence & Factory Robotics at BMW Group." *The Device Chronicle,* April 11. https://medium.com/the-device-chronicle/embedded-intelligence-factory-robotics-at-bmw-group-f12c66249a4b.

CIPESA (Collaboration on International ICT Policy for East and Southern Africa). 2023. "Uganda's Digital ID System Hinders Citizens' Access to Social Services." CIPESA, October 23. https://cipesa.org/2023/10/ugandas-digital-id-system-hinders-citizens-access-to-social-services/.

Daily News Egypt. 2025. "Egypt to Analyse 3.5 Billion E-Invoices, Receipts to Boost Economy, Service Quality: Finance Minister." *Daily News Egypt,* November 24. https://www.dailynewsegypt.com/2025/11/24/egypt-to-analyse-3-5-billion-e-invoices-receipts-to-boost-economy-service-quality-finance-minister/.

Dodoo, J. E., H. Al-Samarraie, and A. I. Alzahrani. 2021. "Telemedicine Use in Sub-Saharan Africa: Barriers and Policy Recommendations for Covid-19 and Beyond." *International Journal of Medical Informatics* 151: 104467. https://doi.org/10.1016/j.ijmedinf.2021.104467.

Dupoux, P., Q. Dhanani, T. Oyekan, S. Rafiq, and K. Yearwood. 2022. "Africa's Opportunity in Digital Skills and Climate Analytics." BCG Global, October 28. https://www.bcg.com/publications/2022/africas-opportunity-in-digital-skills.

Ebatamehi, S. 2025. "Top 10 Online and Distance Learning Institutions in Africa 2025." *The African Exponent,* March 22. https://www.africanexponent.com/top-10-online-and-distance-learning-institutions-in-africa-2025/.

ECA (United Nations Economic Commission for Africa). 2024. "Pace of Progress on the Sustainable Development Goals Is Insufficient to Achieve Set Targets by 2030—Joint Report." April 21. ECA. https://www.uneca.org/stories/pace-of-progress-on-the-sustainable-development-goals-is-insufficient-to-achieve-set-targets.

ECA (United Nations Economic Commission for Africa). 2025. "Tanzania's Path toward a National Data Governance Framework." ECA. https://www.uneca.org/stories/tanzania%E2%80%99s-path-toward-a-national-data-governance-framework.

Enaifoghe, A., and N. Ndebele. 2023. "Examining the Barriers to the Adoption and Integration of Information Communication Technologies as e-Government in Africa." *International Journal of Research in Business and Social Science* 12 (7): 383–393. https://doi.org/10.20525/ijrbs.v12i7.2723.

Farrell, G., S. Isaacs, and M. Trucano. 2007. *The NEPAD e-Schools Demonstration Project: A Work in Progress.* World Bank. https://documents1.worldbank.org/curated/en/208421468140054464/pdf/408800NEPAD0e11blic0Report01PUBLIC1.pdf.

Fedderke, J. 2012. "The Cost of Rigidity: The Case of the South African Labor Market." Working Paper 290. Economic Research Southern Africa (ERSA). https://econrsa.org/wp-content/uploads/2022/06/wp290.pdf.

Frontiers. 2025. "Political Economies of Science, Technologies and Innovation Policies for Achieving the Sustainable Development Goals in Africa." Accessed January 23, 2026. https://www.frontiersin.org/research-topics/22038/political-economies-of-science-technology-and-innovation-policies-for-achieving-the-sustainable-development-goals-in-africa/magazine.

Gakwaya, O., U. Meier-Hahn, R. O. Mbouna, L. Wannemacher, T. Beutel, M. Gericke, J. Gross, F. Henrich, A. Kaiser-Yuecel, J. Krewer, B. Onuoha, J. Pohle, N.-L. Siedler, S. Weiss, and F. von Weizsäcker. 2020. *Blockchain in Africa: Opportunities and Challenges for the Next Decade.* Smart Africa. https://smartafrica.org/wp-content/uploads/2020/12/Final-White-Paper-1-Blockchain-in-Africa-Opportunities-and-Challenges-for-The-Next-Decades.pdf?utm_source=chatgpt.com.

Gbolahan, O., E. Kokori, O. Osaghae, Z. D. Lawal, and T. Olaogun. 2023. "Telehealth in Africa: Evolution and Transformative Impact Before, During and After COVID-19: A Narrative Review." *Journal of Global Health Science* 5 (2): e14. https://doi.org/10.35500/jghs.2023.5.e14.

GEM Team. 2024. *GEM Report.* GEM. https://education-estimates.org/completion/.

Hotter, A. 2023. "DRC Must Formalize Artisanal Cobalt, Kick-Start Buying, Report Says." *Fastmarkets,* February 9. https://www.fastmarkets.com/insights/drc-must-formalize-artisanal-cobalt/.

Liou, J. 2023. "What Are Small Modular Reactors (SMRs)?" September 13.International Atomic Energy Agency. http://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs.

IAEA (International Atomic Energy Agency). 2025. "Outlook for Nuclear Energy in Africa." IAEA, Vienna. https://www.iaea.org/publications/15896/outlook-for-nuclear-energy-in-africa.

IFC (International Finance Corporation). 2018. "Esoko Empowers Farmers, One Text at a Time." IFC, December 12. https://doi.org/10/esoko-empowers-farmers-one-text-at-a-time.

IFC (International Finance Corporation). 2019. *Digital Skills in Sub-Saharan Africa: Spotlight on Ghana.* IFC, Washington, DC. https://www.ifc.org/content/dam/ifc/doc/mgrt/digital-skills-final-web-5-7-19.pdf?utm_source=chatgpt.com.

ILO (International Labour Organization). 2023. *Generative AI and Jobs: A Global Analysis of Potential Effects on Job Quantity and Quality.* ILO, Geneva. https://www.ilo.org/publications/generative-ai-and-jobs-global-analysis-potential-effects-job-quantity-and.

ILO (International Labour Organization). 2024. *Mind the AI Divide: Shaping a Global Perspective on the Future of Work.* ILO, Geneva. https://www.ilo.org/publications/major-publications/mind-ai-divide-shaping-global-perspective-future-work.

ILO (International Labour Organization). 2025a. *ILOSTAT Data Explorer.* ILO, Geneva. https://rshiny.ilo.org/dataexplorer72/?lang=en.

ILO (International Labour Organization). 2025b. "The Leading Source of Labour Statistics." ILOSTAT. Accessed September 15, 2025. https://ilostat.ilo.org/.

Independent Evaluation Team. 2022. *Machine Learning in Education: Identifying Girls at Risk of Dropping Out of School.* Girls' Education Challenge. https://girlseducationchallenge.org/media/oqad2n0v/gec-ii-machine-learning_feb2022.pdf.

Internal Audit Foundation. 2026. *Risk in Focus 2026: Africa Report.* Internal Audit Foundation. https://www.theiia.org/latest-research-and-products/risk-in-focus/2026/2026-africa-report.

ITU (International Telecommunication Union). 2025. "WSIS Stocktaking Success Stories Report 2025." ITU, Geneva. https://www.itu.int/net4/wsis/forum/2025/es/Files/outcomes/draft/WSISStocktakingSuccessStories-2025Report.pdf.

Johal, S., and D. Araya. 2017. "Work and Social Policy in the Age of Artificial Intelligence." Brookings Institution, February 28. https://www.brookings.edu/articles/work-and-social-policy-in-the-age-of-artificial-intelligence/.

Khaled, H. E. 2024. "The Application of the Electronic Invoice Tax System in Egypt and Its Effect on Taxpayer Compliance: The Mediating Role of Taxpayer Satisfaction."

Khalid, M. 2023. "Egypt Collects EGP 8.8 Bln from Tax Evaders over 2.5 Years." *Ahram Online.* https://english.ahram.org.eg/News/505263.aspx.

Khasru, S. M., and R. E. S. Anik. 2025. "AI and Africa: The Unexplored Frontier of Innovation and Inclusivity." T20 South Africa, July 21. https://t20southafrica.org/commentaries/ai-and-africa-the-unexplored-frontier-of-innovation-and-inclusivity/.

Kibanga, W., C. Munishi, H. Ntissi, P. Ndayishimiye, D. T. Myemba, E. Mfinanga, R. F. Mutagonda, and E. Kaale. 2025. "Vaccine Handling Practices and Conformity to Cold Chain Temperature Requirements in Selected Regions of Tanzania: A Descriptive Cross-Sectional Study." *Journal of Pharmaceutical Policy and Practice* 18 (1): 2479062. https://doi.org/10.1080/20523211.2025.2479062.

Kukulska-Hulme, A., R. A. Giri, S. Dawadi, K. R. Devkota, and M. Gaved. 2023. "Languages and Technologies in Education at School and Outside of School: Perspectives from Young People in Low-Resource Countries in Africa and Asia." *Frontiers in Communication* 8: 1081155. https://doi.org/10.3389/fcomm.2023.1081155.

Kuyoro, M., U. Bagus, and K. Dharmadhikary. 2025. "The Quest for Gender Parity in African Tech." McKinsey & Company, August 28. https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/closing-the-loop-the-quest-for-gender-parity-in-african-tech.

Kuyoro, M., U. Bagus, A. Bensrhir, and Z. Bobat. 2025. "Leading, Not Lagging: Africa's Gen AI Opportunity." McKinsey & Company, May 12. https://www.mckinsey.com/capabilities/quantumblack/our-insights/leading-not-lagging-africas-gen-ai-opportunity#/.

Kuyoro, M., U. Bagus, A. Bensrhir, and Z. Bobat. 2025. "Leading, Not Lagging: Africa's Gen AI Opportunity." McKinsey & Company, May 12. https://www.mckinsey.com/capabilities/quantumblack/our-insights/leading-not-lagging-africas-gen-ai-opportunity#/.

Mahlangu, J., G. Taunyane, B. Moosa, and C. Okoro. 2025. "Using Blockchain and Digital Land Registries to Enhance Land Management and Tenure." *CIB Conferences* 1 (1). https://doi.org/10.7771/3067-4883.2070.

Maisiri, J., and S. Musonza. 2025. "The Cultural Cost of AI in Africa's Education Systems." UNESCO, July 20. https://www.unesco.org/en/articles/cultural-cost-ai-africas-education-systems.

Masakhane Community. 2025. *Masakhane African Languages Hub.* Accessed September 15, 2025. https://www.masakhane.io/.

McKinsey & Company. 2023. "Economic Potential of Generative AI." McKinsey & Company, June 14. https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-economic-potential-of-generative-ai-the-next-productivity-frontier#/.

Mduma, N., K. Kalegele, and D. Machuve. 2019. "An Ensemble Predictive Model Based Prototype for Student Drop-Out in Secondary Schools." *Journal of Information Systems Engineering & Management* 4 (3). https://doi.org/10.29333/jisem/5893.

Microsoft. 2024. "Microsoft and G42 Announce $1 Billion Comprehensive Digital Ecosystem Initiative for Kenya." Microsoft, May 22. https://news.microsoft.com/source/2024/05/22/microsoft-and-g42-announce-1-billion-comprehensive-digital-ecosystem-initiative-for-kenya/.

Mofawtar. 2025. "Digital Tax Transformation in Egypt." Accessed January 29, 2026. https://mofawtar.com/en/digital-tax-transformation-in-egypt/.

M-Shule Ltd. n.d. *M-Shule.* Accessed September 15, 2025. https://www.mshule.com/.

Munung, N. S., C. Staunton, O. Mazibuko, P. J. Wall, and A. Wonkam. 2024. "Data Protection Legislation in Africa and Pathways for Enhancing Compliance in Big Data Health Research." *Health Research Policy and Systems* 22 (1): 145. https://doi.org/10.1186/s12961-024-01230-7.

Musa, S. M., U. A. Haruna, E. Manirambona, G. Eshun, D. M. Ahmad, D. A. Dada, A. A. Gololo, S. S. Musa, A. K. Abdulkadir, and D. E. Lucero-Prisno III. 2023. "Paucity of Health Data in Africa: An Obstacle to Digital Health Implementation and Evidence-Based Practice." *Public Health Reviews* 44: 1605821. https://doi.org/10.3389/phrs.2023.1605821.

Nagano, Y., R. Miyashita, and A. Yamanaka. 2025. *Africa's AI Talent Development Landscape – Promoting the Empowerment of Africa through AI Talent Development.* JICA (Japan International Cooperation Agency). https://www.jica.go.jp/english/about/dx/publication/2025/ai_africa.html.

Ndaka, C. 2024. "Towards Equitable and Inclusive Digital Learning in Kenya." April 21. Pulte Institute for Global Development. https://pulte.nd.edu/news/towards-equitable-and-inclusive-digital-learning-in-kenya/.

Nikitina, I., and T. Ishchenko. 2024. "The Impact of AI on Teachers: Support or Replacement?" *Scientific Journal of Polonia University* 65 (4): 93–99. https://doi.org/10.23856/6511.

Nsyengula, S., J. E. Haule, W. Mhagama, J. Wang'uba Okello, and A. Yassin. 2025. "Challenges and Opportunities for Technology and Language Learning in Sub-Saharan Africa." *Journal of Classroom Action Research* 4 (1): 7–14. https://doi.org/10.52622/jcar.v4i1.360.

OECD (Organisation for Economic Co-operation and Development). 2020. "The OECD Digital Government Policy Framework: Six Dimensions of a Digital Government." OECD Public Governance Policy Papers Vol. 02. OECD, Paris. https://doi.org/10.1787/f64fed2a-en.

OECD (Organisation for Economic Co-operation and Development). 2022. *The Effects of AI on the Working Lives of Women.* OECD, March 7. https://www.oecd.org/en/publications/the-effects-of-ai-on-the-working-lives-of-women_14e9b92c-en.html.

Ojo, A. 2025. "Solar Dominates Africa's Energy Investments, but Millions Remain in the Dark." *TechCabal Insights.* https://insights.techcabal.com/solar-dominates-africas-energy-investments-but-millions-remain-in-the-dark/.

Paul, S. 2023. "BMW Roslyn's 50-Year Journey and Looking into the Future." *BMW Blog,* November 4. https://www.bmwblog.com/2023/11/04/bmw-plant-rosslyn/.

Policy@Sussex. 2018. *How Do Political Economy Factors Influence the Evolution of Science Funding in Sub-Saharan Africa?* Policy Brief, June. https://sgciafrica.org/resource/how-do-political-economy-factors-influence-the-evolution-of-science-funding-in-ssa/.

Pritchett, L. 2017. "Why Are Geniuses Destroying Jobs in Uganda?" Center for Global Development, June 15. https://www.cgdev.org/blog/why-are-geniuses-destroying-jobs-uganda.

Puchert, D. 2025. "Good News for Vodacom and MTN in South Africa." July 22. MyBroadband. https://mybroadband.co.za/news/telecoms/603413-good-news-for-vodacom-and-mtn-in-south-africa.html.

Ramaite, A., & Roux, A. le. (2024, September 12). Accelerate, extend or abandon? Africa's SDG dilemma |. https://issafrica.org/iss-today/accelerate-extend-or-abandon-africa-s-sdg-dilemma

Ramachandran, M., and C. Akpata. 2025. "The Technology Infrastructure Revolution: Africa's Opportunities for the Next Frontier." *International Telecoms Week Africa,* August 1. https://www.internationaltelecomsweekafrica.com/africa-connectivity-insights/technology-infrastructure-revolution-africas-opportunities-next-frontier.

RCS Global. 2021. *Better Mining Impact Report 2021.* RCS Global. https://www.rcsglobal.com/pdfs/Better_Mining_Impact_Report_2021.pdf.

Rivers, P. A., J. K. Rivers, and V. Hazell. 2015. "Africa and Technology in Higher Education: Trends, Challenges, and Promise." *International Journal for Innovation Education and Research* 3 (5): 14–31. https://doi.org/10.31686/ijier.vol3.iss5.354.

Rodrik, D., and S. Stantcheva. 2021. "A Policy Matrix for Inclusive Prosperity."

Safaricom. 2024. Safaricom PLC Annual Report and Financial Statements 2024. Safaricom, Nairobi. https://www.safaricom.co.ke/annualreport_2024/wp-content/uploads/2024/07/safaricom-annual-report.pdf.

Silva, S. J. de, T. Strauss, and N. Morisho. 2019. *The Mutoshi Pilot Project.*

Singh, D. 2025. "How Blockchain for P2P Energy Trading Is the Next Big Thing." Debut Infotech, June 19. https://www.debutinfotech.com/blog/blockchain-for-p2p-energy-trading.

Sithole, V. L., and I. Mbukanma. 2024. "Prospects and Challenges to ICT Adoption in Teaching and Learning at Rural South African Universities: A Systematic Review." *Research in Social Sciences and Technology* 9 (3): 178–193. https://doi.org/10.46303/ressat.2024.54.

Skidmore, Z. 2024. "Teraco Starts Work on 120MW Solar Farm to Power South African Data Centers." *Data Center Dynamics,* November 12. https://www.datacenterdynamics.com/en/news/teraco-starts-work-on-120mw-solar-farm-to-power-south-african-data-centers/.

Spice, K. J. 2025. "The Impact of Artificial Intelligence in Secondary Education: A Case Study of Wellspring Academy, Rwanda." *Journal of Research Innovation and Implications in Education.* https://doi.org/10.59765/jriie.9.2.111.

Solis, B. 2025. "Defying Outages: The Struggles and Strategies of Businesses Facing Unreliable Electricity." Global Indicators Brief 32. World Bank, Washington, DC.

Tamirat, B., F. Mazuguni, M. Bamutura, K. Mercy, K. M. Nyarko, B. Tilahun, K. N. Alinon, and Y. K. Tebeje. 2024. "Africa CDC Spearheading the Strengthening of Health Information Exchange in Africa." *The Lancet Digital Health* 6 (6): e382–e384. https://doi.org/10.1016/S2589-7500(24)00068-2.

Thiongane, P. S. 2025. "Bank of Algeria Joins PAPSS Network, Accelerating Financial Integration in Africa as Algeria Prepares to Host IATF 2025." Press Release, August 15. Pan-African Payment and Settlement System, Cairo. https://papss.com/media/bank-of-algeria-joins-papss-network-accelerating-financial-integration-in-africa-as-algeria-prepares-to-host-iatf-2025/.

Turner & Townsend. 2024. "Data Centre Cost Trends—Data Centre Cost Index 2024." https://reports.turnerandtownsend.com/dcci-2024/data-centre-cost-trends.

UNCTAD (United Nations Conference on Trade and Development). 2021. *Digital Economy Report 2021.* United Nations, Geneva. https://unctad.org/system/files/official-document/der2021_en.pdf.

UNCTAD (United Nations Conference on Trade and Development). 2025a. *Technology and Innovation Report 2025: Inclusive Artificial Intelligence for Development.* United Nations, Geneva. https://unctad.org/system/files/official-document/tir2025_en.pdf.

UNCTAD (United Nations Conference on Trade and Development). 2025b. "Africa's Vulnerability to Global Shocks Highlights Need for Stronger Regional Trade." UNCTAD, February 10. https://unctad.org/news/africas-vulnerability-global-shocks-highlights-need-stronger-regional-trade.

UNCTAD (United Nations Conference on Trade and Development). 2025c. "Data Protection and Privacy Legislation Worldwide." Accessed September 12, 2025. https://unctad.org/page/data-protection-and-privacy-legislation-worldwide.

UNDESA (United Nations Department of Economic and Social Affairs). 2017. *The Impact of the Technological Revolution on Labour Markets and Income Distribution.* United Nations, New York. https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/2017_Aug_Frontier-Issues-1.pdf.

UNDESA (United Nations Department of Economic and Social Affairs) Population Division. 2024. *World Population Prospects 2024.* United Nations, New York. https://population.un.org/wpp.

Veen, C. van, ISER (Initiative for Social and Economic Rights), and Unwanted Witness. 2021. "'Chased Away and Left to Die.'" Center for Human Rights and Global Justice, June 8. https://chrgj.org/2021-06-08-report-chased-away-left-to-die/.

Venske, T. 2023. *Navigating Digital Sovereignty in Africa: A Review of Key Challenges and Constraints.* Africa-US Forum. https://www.africa-usforum.africa/wp-content/uploads/2024/07/1-TAGP-4_1_Research_Venske_US-China-techwar_FINAL.pdf.

Vinuesa, R., H. Azizpour, I. Leite, M. Balaam, V. Dignum, S. Domisch, A. Felländer, S. D. Langhans, M. Tegmark, and F. Fuso Nerini. 2020. "The Role of Artificial Intelligence in Achieving the Sustainable Development Goals." *Nature Communications* 11(1): 233. https://doi.org/10.1038/s41467-019-14108-y.

WHO (World Health Organization). 2023. *Electrification of Health-Care Facilities.* WHO. https://www.who.int/data/gho/data/themes/database-on-electrification-of-health-care-facilities.

World Bank. 2018. *World Development Report 2018: Learning to Realize Education's Promise.* World Bank, Washington, DC. https://www.worldbank.org/en/publication/wdr2018.

World Bank. 2024. "Digital Transformation Drives Development in Africa." World Bank, January 18. https://www.worldbank.org/en/results/2024/01/18/digital-transformation-drives-development-in-afe-afw-africa.

World Economic Forum. 2020. *The Future of Jobs Report 2020.* World Economic Forum, Geneva.

Yovo, K., and L. Kolani. 2022. "Does Land Title Increase Agricultural Investments and Productivity? Evidence from Togo." *Journal of Innovations and Sustainability* 6 (3): 04. https://doi.org/10.51599/is.2022.06.03.04.

ENDNOTES

1 AfDB 2025.
2 AUC 2020.
3 ITU 2025.
4 PharmAccess report, 2023, https://publications.pharmaccess.org/progress-report-2023/.
5 Ceselli 2022.
6 BMW Group 2025.
7 Paul 2023.
8 Paul 2023.
9 Africa Arbitration 2022.
10 Mahlangu et al. 2025.
11 Arab Republic of Egypt 2023.
12 Daily News Egypt 2025.
13 Mofawtar 2025.
14 Khalid 2023.
15 Khaled 2024.
16 AGRA 2020; IFC 2018.
17 Abdulai et al. 2023.
18 AGRA 2020.
19 Bailey 2025.
20 Bosman 2023.
21 CIPESA 2023.
22 Veen et al. 2021.
23 Farrell et al. 2007.
24 Farrell et al. 2007.
25 Ndaka 2024.
26 Thiongane 2025.
27 Ebatamehi 2025.
28 Masakhane Community 2025.
29 Maisiri and Musonza 2025.
30 Independent Evaluation Team 2022.
31 Mduma et al. 2019.
32 Nikitina and Ishchenko 2024.
33 Spice 2025.
34 Liou 2021.
35 IAEA 2025.
36 UNCTAD 2025b.
37 World Economic Forum 2020.
38 Brynjolfsson et al. 2017; Cazzaniga et al. 2024.
39 UNDESA Population Division 2024.
40 UNDESA 2017.
41 Kuyoro et al. 2025.
42 McKinsey & Company 2023.
43 IFC 2019.
44 ILO 2025b.
45 ILO 2025b.
46 Gakwaya et al. 2020; Singh 2025.
47 ECA 2024; Ramaite and Roux 2024.
48 Vinuesa et al. 2020.
49 OECD 2020; UNCTAD 2021.
50 Gakwaya et al. 2020.
51 Singh 2025.
52 Nagano, Miyashita, and Yamanaka 2025.
53 World Bank 2018.
54 Mismatch data compare an individual's highest level of education completed against the mode (the most common) education level of all workers in the same occupation at the two-digit level of the International Standard Classification of Occupations (ILO 2025a).
55 Angola, Benin, Botswana, Burkina Faso, Egypt, Guinea-Bissau, Kenya, Madagascar, Mali, Mauritius, Mozambique, Rwanda, Senegal, Togo, Zambia, and Zimbabwe. ILO 2025a.
56 UNCTAD 2025a.
57 McKinsey & Company 2023.
58 UNDESA 2017.
59 Bullock et al. 2024.
60 UNDESA 2017.
61 UNDESA 2017.
62 UNCTAD 2025a.
63 AUDA-NEPAD 2024.
64 Internal Audit Foundation 2026.
65 ECA 2025.
66 Africa Data Centres Association 2024.
67 UNCTAD 2021.
68 Turner and Townsend 2024.
69 Solis 2025.
70 Puchert 2025.
71 Safaricom 2024.
72 UNDESA 2017.
73 Fedderke 2012.
74 Frontiers 2025.
75 Policy@Sussex 2018.

CHAPTER 6
POLICY OPTIONS AND ACTIONS

Africa stands at a critical point in its development, with a demographic dividend uniquely positioned to enable it to leapfrog technologically. The continent's economy is rapidly diversifying, with services accounting for 48.8 per cent of GDP, industry for 26 per cent (manufacturing representing 11.3 per cent), and agriculture for 17.9 per cent.[1] This transition signifies a move towards knowledge-driven economic activities. Frontier technologies are playing a vital role in this shift, offering Africa a chance to bypass traditional structural transformation pathways and infrastructure challenges to explore new pathways for growth.

But this report highlights several obstacles—including infrastructure gaps, such as limited access to broadband internet, inadequate supply of modern sources of energy, and insufficient research and development facilities. Additionally, a skills shortage persists, particularly in digital literacy and technical expertise, which limits the full use of frontier technologies. Governance and regulation issues are also prominent, characterized by fragmented international cooperation and geopolitical tensions that hinder progress and innovation. Finally, economic disparities within and between countries may result in uneven diffusion of technology, worsening existing social and economic inequalities.

The empirical analysis in chapter 2 provides direct support for the report's core policy message: frontier technologies can be transformative for Africa, but their economic dividends are conditional on ecosystem readiness. The results indicate that industrial activity delivers the most consistent productivity gains, while skills development yields increasing returns in the medium term after short-run adjustment costs. Information and communications technology deployment is necessary but insufficient, with modest and time-limited effects when pursued in isolation.

This evidence implies that Africa's frontier technology agenda must be framed as a productivity strategy rather than a connectivity strategy. Policies focused solely on digital access risk producing "shallow digitalization" without sustained productivity transformation. The priorities are thus to embed technology adoption in productive sectors and to invest in human capital and complementary capabilities that allow frontier technologies to be absorbed, adapted, and scaled.

This report aligns with the Science, Technology, and Innovation Strategy for Africa 2034, adopted in July 2025, which details the strategic framework for Africa's pursuit of inclusive and sustainable development, aimed at developing, embracing, and using frontier technologies to improve the continent's vital sectors (box 6.1). The strategy seeks "to harness the transformative power of science, technology, and innovation in accelerating Africa's transition into a knowledge-based and innovation-driven continent."

Box 6.1 The Science, Technology and Innovation Strategy for Africa 2034

The Science, Technology and Innovation Strategy for Africa 2034 is a comprehensive blueprint focused on transforming Africa through science, technology, and innovation and guiding the continent towards an integrated, prosperous, and peaceful future driven by competitive capabilities in those domains. It deliberately selects sectors and thematic areas aligned with national and regional priorities, including agriculture, health, information and communications technology, energy, and the environment. The strategy aims to boost support from governments, regional economic blocs, academic institutions, civil society, the private sector, and international partners.

The strategy begins with improving food and nutrition security through smart agriculture, precision farming, and sustainable crop management that tap into Africa's vast agricultural potential. It then prepares for emergencies by advancing medical research, developing vaccines, and strengthening health information systems. It also promotes developing an integrated and connected Africa, featuring top-tier digital infrastructure, robust cybersecurity, and innovative tech solutions. Additionally, it works to ensure access to affordable, reliable energy by focusing on renewable energy, green hydrogen, and sustainable infrastructure. Ultimately, it addresses biodiversity loss and water scarcity while enhancing climate resilience through innovative environmental monitoring and conservation technologies.

© Adobe Stock

SUMMARY AND CONCLUSIONS

Although Africa's GDP growth is expected to increase in the medium term, this report highlights a divergence among oil-importing, oil-exporting, and mineral-rich economies. Growth in oil-importing countries was supported by the decline in crude oil prices in early 2025, which reached as low as $60 per barrel in May 2025, following global uncertainties caused by US tariffs and weaker-than-expected demand in Brazil, China, and India. But this decline in oil prices is likely to have a negative impact on Africa's major oil-exporting countries, especially those that export crude oil, such as Algeria, Angola, and Nigeria. For most oil-exporting countries, petroleum products constitute more than 80 per cent of exports, making them vulnerable to increased volatility and uncertainty. Many African countries continue to face challenges in diversifying their exports, and it remains crucial that they seize the opportunities offered by the African Continental Free Trade Area.

African countries have faced considerable fiscal pressure since the Covid-19 pandemic, including high public debt, rising interest rates, and increasing demand for public spending. The average fiscal deficit is expected to return to pre–Covid-19 pandemic levels in 2025–26, as countries gradually stabilize their fiscal positions through spending rationalization and improved domestic revenue mobilization. Many African countries have implemented electronic tax filing and payment systems to improve the efficiency and effectiveness of tax administration, thereby increasing tax collection. They have also adopted biometric technology to ensure that public programmes are well targeted and have broader coverage, thus optimizing government spending. But these measures need to be further expanded to strengthen domestic resource mobilization, which requires greater investment in infrastructure and policy frameworks.

Poverty, inequality, and unemployment remain major development challenges in Africa. The Least Developed Countries, located mainly in the Sahel and Central Africa, experienced the largest increases in both monetary and multidimensional poverty. Africa has also seen unprecedented urban growth, driven primarily by high fertility rates, the pursuit of employment opportunities, access to essential services, and displacement caused by conflict. The informal economy continues to dominate Africa's urban labour markets, with more than 80 per cent of employment generated in the informal sector, making it the primary source of livelihood for urban populations. With the continent's young population, rapid urbanization, and a growing digital economy, frontier technologies such as artificial intelligence, data science, and financial technology have vast potential to transform economic structures, lift millions out of poverty, and bridge the gender digital divide.

The effects of frontier technologies and innovation vary across countries and sectors, requiring tailored strategies. A one-size-fits-all solution to accelerate the adoption of frontier technologies across countries and sectors in Africa does not exist.

The effects of frontier technologies and innovation vary across countries and sectors, requiring tailored strategies. A one-size-fits-all solution to accelerate the adoption of frontier technologies across countries and sectors in Africa does not exist. Instead, a maturity model approach may be more appropriate because it enables recommendations to be prioritized based on each country's current circumstances—for example, focusing on reliable electricity supply before investing in large-scale data centres or pursuing joint investment in power production and data centres. Such a model should build on the efforts of the UN Regional Hub on Big Data and Data Science and the UN Data Science Leaders Network. Different technology-related actions are required for various sectors: climate-smart reforms

for agriculture, technology-enabled clusters and corridors to boost manufacturing, and digitalization to enable services to flourish (though it requires substantial human capital). Proper sequencing of technologies may also be required to enhance the effectiveness of an investment, such as investing in reliable electricity before data centres.

Skills, industrial capacity, and finance are the key drivers of growth in Africa. Skills and industrial upgrades consistently boost productivity and output, while information and communications technology offers short-term gains in productivity. But financial systems need to be reoriented through innovation bonds, blended financing facilities, and regional credit lines to channel resources into high-productivity sectors. For example, Africa accounts for only about 1 per cent of the global artificial intelligence (AI) and data science talent pool,[2] highlighting a wide skills gap that could limit the continent's participation in the data-driven global economy. Without skilled professionals, public and private institutions cannot effectively manage, analyse, or govern data. Closing this gap requires investing in education, training, and South–South cooperation to develop a pipeline of data scientists, engineers, and policy experts. Building human and infrastructural capacity is crucial not only for adopting frontier technologies but also for shaping global standards and ensuring Africa's voice is heard in international data governance.

Institutional strengthening and regional cooperation are decisive enablers. Stronger governance, regulation, and public procurement systems can consolidate technology gains, while the African Continental Free Trade Area provides the scale to embed innovation in regional value chains. Frontier technologies must also be directed towards climate resilience—from precision agriculture to renewable energy—ensuring Africa's transformation is inclusive and sustainable.

In the modern world, economic competitiveness is based on data. Data have evolved as a foundational resource, rivalling traditional sources of production such as land, labour, and money. For African economies, data's potential extends far beyond efficiency benefits, as data can foster innovation, improve governance, and strengthen social development. Data are one of the most important raw materials that economies need to collect and analyse in usable formats to make informed decisions and improve operations. Data's integration with frontier technologies such as AI, blockchain, and Internet of Things is driving the global economy by creating new opportunities, increasing productivity, and fostering innovation.[3] This provides a chance for Africa to make rapid and substantial strides in new development pathways. But Africa has an incomplete data value chain. Limited data centres, high processing costs, fragmented datasets, and weak integration undermine value creation. As a result, much of Africa's data potential remains untapped or exported without local benefit. Developing robust data ecosystems will require investing in localized storage systems, affordable cloud computing, and interoperable systems that allow both public and private actors to unlock the economic and social value of data.

The cost of technology in Africa is very high, due mainly to inadequate infrastructure. Internet access costs in Africa are among the highest in the world relative to income, and data centre capacity accounts for less than 2 per cent of the global total. Power instability increases storage and processing expenses, while limited competition among service providers contributes to high prices. These barriers disproportionately impact startups, researchers, and small businesses, making data-intensive innovation unsustainable. Unless costs are cut through investment in energy supply, competition, and regional integration, Africa risks being excluded from the global data economy and remaining dependent on external platforms.

POLICY OPTIONS FOR ENHANCED FRONTIER TECHNOLOGY CAPABILITIES

Effectively adopting frontier technologies in Africa extends beyond mere technological advancement. It requires comprehensive support through robust infrastructure, sustained investment in digital literacy, accessible technical assistance, adequate funding, and well-defined policy and regulatory frameworks. Addressing these foundational elements can lead to effective user engagement and meaningful economic development, paving the way for transformative outcomes from frontier technologies. Frontier technologies and innovation (measured by the frontier technology readiness index) deliver delayed but lasting dividends in African economies. Unlike broad innovation inputs that yield only short-lived gains, frontier technologies generate sustained productivity and income growth, with positive effects compounding over the medium to long term. This section outlines a structured approach prioritizing key policy recommendations over the short-, medium-, and long-term horizons, providing a comprehensive roadmap for enhanced frontier technology capabilities. The criteria encompass infrastructure readiness, skills development, robust governance, financial support, strategic partnerships, sectoral focus, and a political commitment to inclusiveness and sustainability.

SHORT-TERM ACTIONS

Strengthening governance of frontier technologies

The governance of frontier technologies should maximize their benefits while minimizing associated risks, considering each country's national plans, priorities, and aspirations. This involves establishing responsive legal, regulatory, and administrative frameworks, along with strong institutions to oversee their implementation. For instance, many African countries are adopting digital bills of rights—frameworks that promote rights-based digital governance. These frameworks seek to uphold freedom, equity, safety, trust, innovation, and global well-being, ensuring that frontier technologies contribute to economic prosperity and social and environmental well-being.

While legal frameworks establish essential norms, standards, and practices, it is equally crucial to build and strengthen institutions that enforce and safeguard citizens' rights, freedoms, and safety. Africa faces substantial gaps in cybercrime, with 95 per cent of respondents in one study citing inadequate training, limited resources, and a lack of access to specialized tools.[4] Many countries lack basic information technology infrastructure to fight cybercrime: only 30 per cent have an incident reporting system, 29 per cent have a digital evidence repository, and 19 per cent have a cyberthreat intelligence database. These deficiencies emphasize the urgent need to strengthen institutions that monitor, prevent, investigate, and prosecute cybercrimes.

The governance of frontier technologies should be treated as innovation infrastructure, with regulation used strategically to enhance market access, investment readiness, and long-term trust. Both developed and developing countries are investing heavily in this area. For example, global spending on AI governance software is projected to reach $15.8 billion by 2030, driven by the need to ensure accuracy, reduce bias, promote responsible use, and comply with tightening regulations. Further, several governance and regulatory institutions should facilitate and drive research, innovation, and entrepreneurship. Traditional compliance-focused approaches are no longer sufficient: advanced tools now enable even small or resource-poor groups to create deepfakes that could influence elections, deploy drones that disrupt critical services, break encryption protecting financial markets, or engineer genotype-targeted bioweapons. Such cases are no longer hypothetical but real threats that have already happened. Therefore, governments should combine robust laws and regulations with investment in awareness, capacity building, and protective technologies that detect, prevent, and trace misuse. This includes training, funding programmes, and targeted campaigns, especially for Africa's many informal, micro, and small firms.

There is also an urgent need to raise public awareness of the benefits, risks, and safety issues associated with frontier technologies, as well as their relevant legal and regulatory frameworks. Helping citizens understand their rights, responsibilities, and potential vulnerabilities is essential to a safe and inclusive society. Such measures may also ensure that citizens avoid seemingly innocent actions that lead them to be on the wrong side of the law.

There is an urgent need to raise public awareness of the benefits, risks, and safety issues associated with frontier technologies, as well as their relevant legal and regulatory frameworks. Helping citizens understand their rights, responsibilities, and potential vulnerabilities is essential to a safe and inclusive society.

Similar concerns extend beyond digital technologies to other frontier technologies such as genetic engineering, gene editing, and nanotechnology. For example, disclosing one individual's genetic makeup can have far-reaching implications for siblings, parents, children, and even future generations, all of whom share similar genetic information. This highlights the ethical and legal complexities surrounding the use of such technologies and the importance of inclusive, rights-based governance. It also underscores the importance of national and regional legislators actively participating in frontier technology governance. This requires legislators to be properly informed and adequately engaged.

Harnessing partnerships to advance frontier technologies

Partnerships are vital for gaining access to resources (funding, talent, and infrastructure), sharing the risks of failure, and navigating complex market entry rules. As the costs of research and development, infrastructure, and technology acquisition increase, partnerships between countries, businesses, and academia are expanding. For example, the US Stargate Project, which involves OpenAI, Oracle, and SoftBank, is expected to invest around $500 billion in AI infrastructure.[5] African countries might also need to build similar alliances to meet the demands of many frontier technologies.

Partnerships may also be essential to reduce the costs associated with accessing frontier technologies, especially for poorer countries. For instance, the Pathogen Genomics Initiatives of the African Centre for Disease Control is a $100 million collaboration involving Illumina and Oxford Nanopore, providing vital next-generation sequencing machines and training; the Gates Foundation and the US Centers for Disease Control and Prevention (offering funding and technical assistance through the Advanced Molecular Detection programme); and Microsoft (supporting the design and construction of the Africa Pathogen Genome Initiative's digital infrastructure, including access to high-performance computing and genomics software from its Life Sciences Division). These efforts enable several countries to access frontier technology solutions at reduced costs.

Partnerships among African organizations are equally important. To that end, ECA facilitated the creation of the Alliance for Entrepreneurial Universities in Africa[6] and has been involved in building biomedical engineering innovation capacity for improved health outcomes. It developed a generic biomedical engineering curriculum that enabled universities on the continent to quickly generate programs tailored to their national and institutional needs. In addition, ECA has been instrumental in establishing the Origin Research and Innovation Labs, a continental platform designed to work with local communities to identify root causes of problems and bring them as challenges to a global community of solvers, using frontier technologies to address the Sustainable Development Goals.[7]

African countries are encouraged to use science diplomacy proactively to align partnerships with the continent's development goals, build research capacity, foster technological advancement, promote dialogue, and strengthen international and regional collaboration.

These efforts should be supplemented by international cooperation through Africa's active participation in reforming the global financial architecture and in articulating the UN Framework Convention on International Tax Cooperation and financing for development outcomes, which could lead to measures that expand country tax bases, domestic resource mobilization, and fiscal space by leveraging the opportunities that come with frontier technologies.

MEDIUM-TERM ACTIONS

Promoting research and development, innovation, and entrepreneurship

Frontier technologies are driven by investment in research and development to create new products and services and enhance existing ones, enabling companies to stay competitive. Africa's gross research and development spending across all sectors in 2023 was an estimated $36.1 billion (in purchasing power parity terms), or about 1.3 per cent of the global total of $2.75 trillion.[8] Most of Africa's research and development is carried out by the public sector rather than by industry, as in advanced countries, and most research and development spending is directed towards agriculture, natural sciences, health, and social sciences. Of the 22 African countries with research and development data, 14 allocated less than 10 per cent of research and development spending to engineering and technology.[9]

Africa needs to grow its research and development base by increasing funding, creating centres of excellence in frontier technology development and adaptation, and improving the policy and regulatory environment for commercializing, seeding, and attracting technology startups (which in turn drives research and development investment). The continent could harness resources from international organizations such as the World Bank that fund higher education centres of excellence.[10] Joint research centres among academia, industry, and government can build research and development infrastructure, develop research talents, and enhance entrepreneurial skills while fostering trust and working relationships. Entrepreneurial skills development could be promoted by embedding it in the curriculum of tertiary education programmes. Innovative funding mechanisms such as the Tertiary Education Trust Fund in Nigeria—which aims to rehabilitate and improve tertiary institutions by funding infrastructure, research, staff training, and instructional materials—should also be promoted.[11]

African countries need to assess and prioritize their research and development investment in frontier technologies and industries. For instance, in which sectors and frontier technologies should a country direct most of its research and development

investment to achieve a strong return and positive spillovers? How can such an investment be directed to stimulate private sector involvement in sectors vital to the country? Should research and development investment focus on adapting and using tested and mature frontier technologies or on frontier technologies?

Africa's fundamental and applied research in frontier technologies is limited. The top 50 universities in AI publications are limited to six countries: Egypt (16), South Africa (11), Algeria (8), Tunisia (8), Morocco (6), and Nigeria (1). The highest ranked university in Africa for AI is placed at 430th globally, and the 50th ranked university in Africa is placed at 1948th globally. Still, the top 50 universities overall in Africa are spread across approximately 17 African countries, with the leading African university ranked 279th worldwide.[12] This indicates a growing gap in frontier technologies within Africa and between Africa and the rest of the world.

Reforming the international financing environment

Expanding investment in research and development, innovation, and entrepreneurship is increasingly constrained by structural features of the international financing environment. High debt service burdens, elevated sovereign risk premia, and limited access to long-term concessional finance reduce fiscal space and raise the cost of capital for innovation-intensive investment. These constraints are reinforced by prevailing sovereign credit-rating practices, which tend to place limited weight on long-term growth potential, climate-resilient investment, and development-enhancing public spending, while amplifying short-term macroeconomic volatility and external shocks.

In this context, reforms to the global financial architecture—including improvements in sovereign debt resolution frameworks, expanded use of state-contingent instruments such as climate-resilient debt clauses and debt-for-climate or debt-for-nature swaps, and a stronger role for multilateral development banks in providing affordable, long-maturity finance—are critical complements to national innovation and research and development policies.

Equally important are reforms to the international credit-rating ecosystem, including greater transparency in rating methodologies, improved treatment of climate risks and long-term investment, and enhanced competition and regional representation in credit-rating provision, to reduce excessive risk premia and better align ratings with development trajectories.

Reforms to the global financial architecture—including improvements in sovereign debt resolution frameworks, expanded use of state-contingent instruments such as climate-resilient debt clauses and debt-for-climate or debt-for-nature swaps, and a stronger role for multilateral development banks in providing affordable, long-maturity finance—are critical complements to national innovation and research and development policies.

A third, complementary priority is reforming the global tax architecture to address persistent revenue leakage and reduce reliance on costly external borrowing. Illicit financial flows, profit shifting, and aggressive tax avoidance by multinational enterprises continue to erode African tax bases. Ongoing negotiations towards a UN-led framework for international tax cooperation provide a critical opportunity to strengthen source-based taxation, improve the taxation of the digital economy, and enhance transparency and information exchange. For African countries, these reforms are central to generating sustainable domestic revenue that can support development spending without exacerbating debt vulnerability.

Overall, reforms to the global financial architecture, the international credit-rating ecosystem, and the global tax architecture are essential complements to

national and regional policy action. When combined with stronger debt management, innovative financing instruments, and private capital through blended finance, thematic bonds, and regional capital markets, these reforms can help close Africa's financing gap for frontier technologies.

De-risking investment in frontier technologies

Investing in frontier technologies entails considerable risk, particularly during the early stages of research and development. These risks are especially pronounced for smaller firms and startups, which often lack the financial resilience to absorb potential losses. In the biopharmaceutical sector, approximately 90 per cent of drug candidates entering Phase 1 clinical trials ultimately fail, highlighting the high-risk nature of early-stage innovation.[13]

To mitigate these risks and encourage private sector involvement, governments often offer various forms of financial support. In South Africa, research and development incentives include a 50 per cent tax deduction on qualifying research and development spending and a 150 per cent tax deduction for pilot or prototype plants used exclusively for research and development.[14] Additionally, capital allowances for research and development–related machinery and equipment can be claimed on an accelerated basis—50 per cent in the first year, 30 per cent in the second year, and 20 per cent in the third year.[15] These measures aim to lessen the cost burden and promote greater private investment in innovation.

Beyond tax incentives, governments can further reduce investment risk by providing sovereign or loan guarantees. These mechanisms offer partial or complete credit protection in the event of a project's failure, thereby encouraging lending and investment in high-risk ventures. Such schemes are well-established in mining and public infrastructure throughout Africa and can be tailored to support investment in frontier technologies.

Market guarantees also play a critical role in creating a more secure investment environment. These may include:

- Regulatory sandboxes or temporary flexible regulatory frameworks that enable real-world testing of innovative products and services (such as drones and AI).
- Fast-track approval pathways for breakthrough or high-impact technologies (such as biopharmaceuticals).
- Advance market commitments, including purchase guarantees or upfront payments upon successful delivery (such as Covid-19 vaccines and renewable energy).
- Exclusive provider agreements for public sector use.

© Adobe Stock

- Public procurement programs designed to pilot, validate, and scale new technologies.

Ultimately, strategies to de-risk investment in frontier technologies should align with broader national objectives such as economic competitiveness, digital sovereignty, health resilience, or climate action and be tailored to the country's innovation ecosystem and industrial capacity.

LONG-TERM ACTIONS

Developing inclusive and dynamic strategic policies, plans, and roadmaps

Frontier technologies are advancing rapidly, necessitating strategic, adaptable, and inclusive policies, plans, and roadmaps. "Strategic" refers to a long-term approach, establishing clear goals, priorities, timelines, and coordination mechanisms over 3–20 years. "Dynamic" means policies must remain flexible, adaptable, and responsive to emerging trends and unforeseen challenges. Equally important, strategic policies and plans must be inclusive, considering the special needs of people with disabilities, in both design and implementation to ensure that diverse interests, concerns, opportunities, and risks across societal groups are considered throughout development, implementation, monitoring, evaluation, and revision. Singapore incorporates "white space" into its technology policies, with dedicated budgets for unexpected developments during implementation.

For Africa, strategic policies and plans on frontier technologies and innovation should be based on research and scientific evidence and directly connected to industrialization, economic diversification, job creation, and national ownership, as outlined in Agenda 2063: The Africa We Want. The Science, Technology and Innovation Policy Design and Implementation Guide, developed by ECA, advises that countries should:

- Establish a clear baseline and define where they aim to be and by when.
- Set specific priorities and measurable targets (see annex 6.1).
- Develop implementation plans detailing timelines, required resources, and the sources, responsible actors, and milestones.
- Include robust monitoring and evaluation systems that define responsibilities, intervals, reporting lines, and follow-up mechanisms.
- Build in flexibility for iterative adjustments.

All these elements should be collectively developed and agreed on by government, industry, civil society, and other stakeholders to obtain commitments, appreciate their challenges, find solutions, and achieve effective implementation (see annex 6.1).

To achieve this, a whole-of-government and integrated approach should be adopted when designing frontier technology and innovation plans and strategies—rather than restricting efforts to a single ministry or department. Countries might consider establishing presidential advisory councils or similar entities dedicated to science, technology, and innovation. These constitutionally mandated bodies, which include representatives from industry, academia, civil society, and government, are often chaired by the president or an equivalent high-level authority, depending on the governance structure. Their primary role is to provide strategic advice to executive leadership, ensuring broad political support and inclusivity in policy development and implementation. Several countries' governments, Algeria, Egypt, Morocco, Rwanda, South Africa, and Tunisia, have demonstrated political commitment to innovation and entrepreneurship. The case of Algeria is illustrated in box 6.2.

For Africa, strategic policies and plans on frontier technologies and innovation should be based on research and scientific evidence and directly connected to industrialization, economic diversification, job creation, and national ownership.

Box 6.2 Political leadership in innovation in Algeria

Algeria demonstrates how high-level political leadership drives innovation and puts it at the centre of national development. Its Ministry of Knowledge Economy, Startups, and Micro Enterprises aims to create a conducive environment for startups and micro-enterprises by providing resources, regulatory frameworks, and support systems. The ministry promotes innovation and technological advancement, supports the establishment and growth of startups, facilitates access to financial resources and markets for micro-enterprises, and enhances the competitiveness of Algerian businesses on a global scale. The ministry's creation was part of a broader strategy to modernize the Algerian economy by embracing a knowledge-based approach. The approach focuses on using human capital, technological advancements, and innovative practices to drive economic growth and development.

The Algerian Startup Fund, initiated by President Abdelmadjid Tebboune in 2020, embodies the government's commitment to developing a knowledge-based economy and reducing dependency on hydrocarbons. It equips Algeria with a modern venture financing vehicle to accelerate economic transformation. The fund supports startups, adopting tools tailored to innovation risk (equity and quasi-equity). It was established in partnership with six public banks and aims to speed up investment decisions, deliver post-investment support (such as hands-on guidance and access to partner networks) and build export readiness. The president has set the ambitious target of creating 20,000 startups and 400,000 jobs by 2029. The government has taken major steps to achieve these targets, including developing a roadmap to boost innovation among young people, encourage entrepreneurship, and stimulate the creation of startups. It has also funded a large network of incubators, with universities playing a central role, enabling students to transform their final-year projects into startups. In addition, the government is mobilizing Algerian skills abroad via a dedicated digital platform to facilitate the remote creation of startups and encourage collaboration with local institutions. Since 2020, over 13,000 startups were created in Algeria. The government also demonstrates leadership at the continental level by organizing the annual African Startup Conference, a pan-African platform for innovation and entrepreneurship.

Building human capital development for the future

Only 13 per cent of African children can read and understand a simple story by the age of 10, just 15 per cent of upper secondary students are enrolled in technical and vocational education training, and the gross enrolment rate in tertiary education is 9 per cent (compared with 42 per cent globally).[16] Efforts to broaden access and enhance performance are urgently needed to empower the population, especially youth and women, with the technology, entrepreneurial, creative, and problem-solving skills needed to use, design, and produce knowledge products.[17]

Countries may need to develop comprehensive national education action plans that include prioritizing context-specific strategies for curriculum reform and the professional development of teachers, with a focus on practical skills. They also aim to promote and expand successful, context-specific solutions and models at the national and regional levels, such as the science, technology, engineering, and mathematics centres in Ethiopia, model schools in Kenya, and technical and vocational education and training in Sierra Leone. Kenya's Competency-Based Curriculum and Zimbabwe's Education 5.0 are other examples of such initiatives.

Countries are encouraged to establish structured collaboration frameworks between universities and industry to ensure that education, particularly in science, technology, engineering, and mathematics (STEM), is aligned with industry and national needs. More importantly, collaboration among educational institutions, industry, and public entities should be open to all, not just STEM trainees. Moreover, they should promote mechanisms that provide industrial work experience to students. Policies to retrain personnel in universities and the public and private sectors in general to harness the opportunities offered by frontier technologies should also be promoted.

Countries may also need to develop platforms for building digital literacy skills that can equip the general population with the skills needed to safely, ethically, and productively apply frontier technologies in their work and daily lives. These could build on existing digital literacy skills that are open, secure, and accessible to all. Furthermore, countries could expand on existing tools, such as generative AI, that are context-specific (languages, accents, dialects, colours, traditions, practices, and the like). Similar measures can build a broader human capital base that can thrive in the rapidly evolving world.

Investing in hard and soft infrastructure

Accelerating the adoption of frontier technologies will require substantial investment in both hard and soft infrastructure at the national and regional levels. Critical infrastructure, including data centres, high-performance computing facilities, cloud computing platforms, and 5G networks, among others, is essential for enabling widespread digital technology use. Additional investment in science, technology, and industrial parks can support the commercialization of emerging innovations. Meanwhile, electric vehicle charging stations play a vital role in facilitating the mass adoption of clean transportation solutions.

Accelerating the adoption of frontier technologies will require substantial investment in both hard and soft infrastructure at the national and regional levels. Critical infrastructure, including data centres, high-performance computing facilities, cloud computing platforms, and 5G networks, among others, is essential for enabling widespread digital technology use.

The success of these advanced systems relies heavily on traditional infrastructure, such as dependable energy, transport, and communication networks. Effective postal and logistics services remain vital for supporting e-commerce and last-mile delivery.

Governments could play a crucial role in both planning and funding infrastructure development, especially where long-term public benefits are involved.

Africa also needs to invest in public digital infrastructure, which allows governments, businesses, and individuals to interact safely and efficiently online. These may include digital identity systems, payment platforms, data registries, cloud infrastructure, and secure communication networks. Such infrastructure forms the foundation for delivering digital public services, promoting financial inclusion, and enabling innovation in the private sector. Innovative financing mechanisms could be used to fund hard and soft infrastructure. For instance, taxes collected from mobile network providers could be reinvested into developing mobile network infrastructure.

POLICY SEQUENCING AND COMPLEMENTARITIES

Effective policy design rests on understanding how innovative data inputs and outputs interact with frontier technologies, including their drivers, consequences, and enabling conditions. This understanding is essential for determining whether policy interventions should be sequenced or deployed in a complementary manner to maximize development gains. Realizing these gains requires carefully considering expected returns on investment, public acceptability, and a country's comparative advantage in adopting, using, and scaling different types of innovative data and frontier technologies.

Chapter 2's disaggregated empirical results provide a concrete basis for sequencing reforms. A practical policy framework is to organize interventions into three overlapping and mutually reinforcing stages.

Stage 1—Build absorptive capacity (priority foundations)

Scale foundational and digital skills, strengthen education-to-employment pathways, and deploy transition-oriented labour-market measures. This stage is critical because investing in skills can generate negative short-run effects due to adjustment and training costs but strong positive effects in the medium term. The evidence implies that early and sustained investment in skills is necessary to manage transition costs and unlock longer-term productivity gains.

Stage 2—Embed technology in productive sectors (industrial and firm capability)

Prioritize the diffusion of frontier technologies into productive activities—particularly high-tech manufacturing, information and communication technology–enabled services, and digitally intensive production. Industrial activity is the most consistent contributor to productivity gains across all horizons, underscoring that technology policy cannot be effective in isolation. Industrial policy and technology policy must be jointly designed to support firm-level learning, scale, and diffusion.

Stage 3—Activate enablers that scale and sustain gains (finance and innovation systems)

Strengthen the allocation of finance towards productive and technology-intensive activities and deepen innovation systems. Weak and inconsistent finance effects indicate that financial deepening alone is insufficient unless it improves the quality of allocation. Similarly, research and development investment requires long gestation; growth payoffs depend on the prior existence of skills, firms, and industrial demand capable of absorbing and commercializing research outputs.

This sequencing should not be interpreted as linear. Information and communication technology and data infrastructure investment is needed throughout the process, but their growth dividends are maximized when skills development and productive capabilities advance in parallel rather than in isolation.

To operationalize this framework, countries should systematically profile the expected returns on alternative innovative data applications and frontier technologies. Cost–benefit analysis can help identify options with the greatest potential for scalability, sustainability, and replicability, focusing on quantifiable productivity, fiscal, and investment

outcomes. These assessments should be complemented by evaluations of environmental and socio-cultural factors to ensure contextual relevance, public ownership, and political feasibility.

Finally, to ensure that frontier technology adoption supports economic transformation rather than growth alone—the central objective of this report—policy choices must explicitly assess distributional and labour market effects. Pro-poor transmission mechanisms, particularly employment creation and job quality, should be evaluated alongside efficiency and environmental considerations. Understanding labour mobility, literacy and digital skills gaps, and workforce composition is essential for gauging whether frontier technologies can generate inclusive employment. At the continental level, comparative analysis can further support regional partnerships and cross-border specialization, enabling countries to leverage complementary capabilities in regional and global value chains.

To ensure that frontier technology adoption supports economic transformation rather than growth alone—the central objective of this report—policy choices must explicitly assess distributional and labour market effects.

ANNEX 6.1 THE CASE OF THAILAND AI STRATEGY 2022–27

The aim of the strategy is for Thailand to have an effective ecosystem for developing and applying AI, which is expected to enhance the economy and improve our quality of life by 2027. This will be achieved through five strategies and 15 work plans.

Strategy 1: Preparing Thailand's readiness in social, ethics, law, and regulation for AI application

- At least 600,000 Thai people have awareness of AI law and ethics
- An ai law and regulation is enforced

Strategy 2: Developing infrastructure for sustainable AI development

- Increase Thailand's Government AI Readiness index to rank among the top 50 globally
- Increasing digital infrastructure investment 10 per cent a year to support AI development in both public and private sectors

Strategy 3: Increasing human capability and improving AI education

- Creating more than 30,000 AI talents within 6 years

Strategy 4: Driving AI technology and innovation development

- Strengthen AI technology by developing at least 100 R&D prototypes within 6 years
- Wide adoption of AI research, development, and innovation helps create business & social impact of at least 48 billion Baht by 2027

Strategy 5: Promoting the use of AI in public and private sectors

- The number of agencies (government, business, and new entrepreneurs) using AI innovation has increased to at least 600 agencies in 6 years
- AI applications increase Thailand's AI competitiveness
- Even without the rest of the details, this strategy has a clear aim, targets and measurable potential impact.

Source: http://www.ai.in.th/en/about-ai-thailand/.

REFERENCES

AEUA (Alliance for Entrepreneurial Universities in Africa). 2026. *Alliance for Entrepreneurial Universities in Africa.* AEUA. https://www.aeuafrica.org/.

AUDA–NEPAD (African Union Development Agency–New Partnership for Africa's Development). 2019. *African Innovation Outlook: Third Edition.* AUDA-NEPAD. https://au.int/sites/default/files/documents/38122-doc-aio_3rd_edition_final_eng_repro.pdf.

Department of Science and Technology (South Africa). 2016. *Scientific and Technological Research and Development Tax Incentive: Guidelines for Applicants.* Government of South Africa, Pretoria. https://www.dsti.gov.za/rdtax/images/tax-incentive/RD_Tax_Incentive_Guidelines_for_Applicants.pdf.

INTERPOL (International Criminal Police Organization). 2025. *Africa Cyberthreat Assessment Report 2025.* INTERPOL, Lyon.

KPMG. 2025. *Global R&D Incentives Guide.* KPMG. https://assets.kpmg.com/content/dam/kpmg/us/pdf/2021/05/tnf-global-rd-incentives-guide-may11-2021.pdf.

Origin Research and Innovation Labs. n.d. *Origin Research & Innovation Labs.* Accessed January 29, 2026. https://originlabsafrica.org/.

Seetharaman, D. 2025. "OpenAI, Oracle, SoftBank Plan Five New AI Data Centres for $500 Billion Stargate Project." *Reuters,* September 23. https://www.reuters.com/business/media-telecom/openai-oracle-softbank-plan-five-new-ai-data-centers-500-billion-stargate-2025-09-23/.

Spurt Solutions. 2024. *State of Artificial Intelligence Adoption in Africa.* Spurt Solutions. https://assets.State_of_Artificial_Intelligence_in_Africa.pdf.

Sun, D., W. Gao, H. Hu, and S. Zhou. 2022. "Why 90% of Clinical Drug Development Fails and How to Improve It?" *Acta Pharmaceutica Sinica B* 12 (7): 3049–3062. https://doi.org/10.1016/j.apsb.2022.02.002.

TETFund (Tertiary Education Trust Fund). n.d. *TETFund.* https://tetfund.gov.ng/.

UNDESA (United Nations Department of Economic and Social Affairs). 2018. *World Economic and Social Survey 2018: Frontier Technologies for Sustainable Development.* United Nations, New York. https://policy.desa.un.org/sites/default/files/inline-images/eapd2023/WESS2018_ch1_en.pdf.

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2024. *Forum on Higher Education in Africa: A Driver for Sustainable Development.* UNESCO, Nairobi. https://www.unesco.org/sites/default/files/medias/fichiers/2024/12/higher-education-africa-cn-en_1.pdf.

UniRank. 2025. *Top 200 Universities in Africa: 2025 African University Ranking.* UniRank. https://www.unirank.org/africa/top-200/.

United Nations. 2025. "Africa: Foreign Investment Hit Record High in 2024." UNData.

WIPO (World Intellectual Property Organization). 2024. "End of Year Edition – Against All Odds, Global R&D Has Grown Close to USD 3 Trillion in 2023." WIPO, December 18. https://www.wipo.int/web/global-innovation-index/w/blogs/2024/end-of-year-edition.

World Bank. 2025. "Africa's Higher Education Centers of Excellence: Celebrating a Decade of Transformative Journey in Revolutionizing Africa's Contribution to Global Research and Innovation." World Bank, April 7. https://www.worldbank.org/en/news/press-release/2025/04/07/africa-higher-education-centers-of-excellence-africa-contribution-to-global-research-and-innovation.

World Economic Forum. 2022. *Catalysing Education 4.0: Investing in the Future of Learning for a Human-Centric Recovery.* World Economic Forum, Geneva. https://www3.weforum.org/docs/WEF_Catalysing_Education_4.0_2022.pdf.

ENDNOTES

1 Based on ECA calculations using United Nations (2025) data.
2 Spurt Solutions 2024.
3 UNDESA 2018.
4 INTERPOL 2025.
5 Seetharaman 2025.
6 AEUA 2026.
7 Origin Research and Innovation Labs n.d.
8 World Intellectual Property Organization 2024.
9 AUDA-NEPAD 2019.
10 World Bank 2025.
11 TETFund n.d.
12 UniRank 2025.
13 Sun et al. 2022.
14 Department of Science and Technology 2016.
15 KPMG 2025.
16 UNESCO 2024.
17 World Economic Forum 2022.

STATISTICAL NOTE

This year's Economic Report on Africa is based on the latest updated and harmonized data from a wide range of sources. The report draws on both economic and social data, organized into thematic groups such as growth, fiscal, monetary, trade, frontier technologies, innovation, commodities, poverty, inequality, human capacity, and energy. Data are sourced from international organizations, government departments, and independent peer-reviewed articles, while specialized databases are clearly noted individually, where applicable. Data in this report may differ from previous editions due to recent revisions and updates. Unless otherwise noted, data cover all 54 ECA member states, organized in five subregions under UNECA's classification: North Africa, West Africa, Central Africa, East Africa, and Southern Africa. Countries are also classified into economic groupings which include oil exporting, oil importing, and mineral rich countries, aggregated based on IMF country classifications.

The primary economic and social data variables are obtained from the United Nations Economic Commission for Africa's (UNECA) own database, as well as leading international organizations, including (in alphabetical order) the International Labour Organization (ILO), the United Nations Conference on Trade and Development (UNCTAD), and the United Nations Department of Economic and Social Affairs (UN-DESA). The UN-DESA Global Economic Outlook database provides comparable data on GDP growth for all developing global regions and all African countries, with real GDP growth rates calculated using 2015 as the base year. Subregional growth and inflation rates for country groupings are derived as weighted averages, with weights based on GDP in 2015 prices. The report also made use of statistical databases from the Economist Intelligence Unit (EIU), the International Monetary Fund (IMF), and the World Bank. These sources provide a robust foundation for analysing key economic indicators, trends, and forecasts across the continent.

The report incorporates thematic data to address specific areas of interest. Social variables, such as labor and gender equality, are sourced from ILO, UNDP, UNESCO, and the World Bank. Frontier technology and innovation-related data are drawn from UNCTAD, WIPO, ITU, Statistica, and the Africa Block Chain Report, while energy data are obtained from UNCTAD, the World Bank, and International Renewable Energy Agency (IRENA).

In addition to the primary sources, the report incorporates data from selected government departments in African countries, as well as specialized databases such as ITedge, McKinsery and Company, Mapping AI Start-Ups in Africa, Precedence Research, Qureca, and Price Waterhouse and Coopers. Data from independent peer-reviewed articles are also cited both in the text and in the chapter-specific reference lists. All data from sub-agency databases are also explicitly noted in the footnotes or below the relevant figures and tables.

Harnessing data and frontier technologies offers significant opportunities for Africa to break from low-productivity trajectory and forge new pathways for inclusive and sustainable growth. Strategic adoption of frontier technologies across sectors offers the potential to leapfrog traditional development pathways, raise efficiency, support industrial upgrading, increase productivity, attract investment, create jobs, and promote economic diversification. Data, as a critical economic asset, and the new oil fuelling frontier technologies have also been instrumental in driving economic transformation worldwide and thus hold immense potential to accelerate Africa's growth, innovation, and overall development.

The Economic Report on Africa 2026, using a mixed-methods approach that includes empirical analysis and case studies, highlights the impact of innovation on economic growth and development through enhanced productivity. It also highlights the opportunities, risks, and challenges in harnessing data and frontier technologies and innovations to drive economic transformation, and the actions African countries can take to maximize the transformative potential.

The report finds that enhancing Africa's sectoral productivity and closing the productivity gap through technology and innovation requires differentiated strategies, with agriculture at risk of being left behind without climate-smart reforms, irrigation, and targeted finance. Manufacturing emerges as Africa's anchor for structural transformation through technology and innovation-enabled clusters and corridors. And services thrive on digitalization and finance, but with limited human capital to sustain growth. Institutions and regional cooperation are decisive enablers for technology and innovation to flourish.

What are the keys to harnessing data and frontier technology to enhance Africa's economic transformation?

- Strengthening governance structures and harnessing partnerships.
- Promoting R&D, innovation, and entrepreneurship.
- Reforming the international financing environment and de-risking investment in frontier technologies.
- Developing inclusive and dynamic strategic policies, plans, and roadmaps.
- Promoting human capital development for the future. Investing in hard and soft infrastructure.
- Taking advantage of the opportunities that come with implementing the AfCFTA to provide the scale to embed innovation in regional value chains.

ISBN: 9789211548662

Printed in Addis Ababa, Ethiopia by the ECA Printing and Publishing Unit. ISO 14001:2015 certified.
Printed on chlorine free paper.