From Best-Practice to Best-Fit: Contextualising Innovation Policy for Transformation

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Accelerating Africa's industrialisation and sustainable development through transformative innovation

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FOREWORD

The African Innovation Outlook (AIO) is a series of continental reports jointly published by the African Union Development Agency (AUDA-NEPAD) and the African Union Commission (AUC) to assess the state of Research and Experimental Development (R&D) and innovation across the African continent. These reports are produced at the end or during each project segment and are part of the African Science, Technology and Innovation Indicators (ASTII) Initiative, which aims to strengthen the capacity of African Union Member States to measure and monitor R&D and innovation activities. Since 2007 Africa has measured its research inputs, focusing on personnel and expenditures, including both current and capital costs. The continent is also evaluating its research outputs and innovation competitiveness in compliance with the continental framework on science, technology and innovation (STI) and the goals outlined in the 2030 Agenda for Sustainable Development, specifically goals 9 and 17.

The ASTII team at AUDA-NEPAD in Johannesburg (South Africa) and the African Observatory of Science, Technology and Innovation (AOSTI) in Malabo, Equatorial Guinea, continuously work to strengthen the capacities of African Union (AU) Member States in synergy with regional economic communities (RECs). They aim to leverage STI as an enabler for socio-economic transformation and sustainable development in the context of the current 4th and 5th industrial revolutions. The prefaces of the AIO reports are typically authored by representatives from both the AUC and AUDA-NEPAD. In the Third African Innovation Outlook (AIO-III), published in 2019, contributions were made by H.E. Professor Sarah M.E. Anyang Agbor, Commissioner for the Department of Human Resources, Science and Technology at the African Union Commission and H.E. Dr Ibrahim Assane Mayaki, former CEO of AUDA-NEPAD, who engaged in fieldwork as part of the national survey process to collect data on R&D and innovation.

Moreover, the AIO-2019 report covers a period during which significant developments occurred in the African Union policy processes. For instance, in 2013, nearly at the same time as the launch of the AIO-2014 report, the AU adopted its Agenda 2063, a 50-year vision for realising the aspirations of “The Africa We Want” by 2063, along with the First Ten-Year Implementation Plan of Agenda 2063, which includes programmes aimed at promoting science, technology and innovation and applying STI in the continent’s economic development activities. In 2014, the AU adopted the Science, Technology and Innovation Strategy for Africa, 2014-2024 (STISA 2024), which outlines the prerequisites, pillars, priority areas and investments necessary to facilitate advancement in STI. On the global stage, the 17 Sustainable Development Goals (SDGs) were adopted, enabling the ASTII programme to examine future measurements essential for monitoring STI development across the continent.

The AIO-2024 report covers the period from the onset of Covid-19 in 2020 to the adoption of the second iteration of STISA (2025-2034), endorsed by the 5th Specialised Technical Committee on Education, Science, Technology and Innovation (STC-ESTI) in alignment with the second decade of acceleration outlined in Agenda 2063’s Second Ten-Year Implementation Plan. The adoption of STISA-2034 in 2024 followed changes within the AUC Department of Human Resources, Science and Technology (AUC-HRST), which is now known as the Department of Education, Science, Technology and Innovation (AUC-ESTI). Within the CEO’s Office, AUDA-NEPAD established the Office of Science, Technology and Innovation (OSTI), under which the ASTII programme operates, supporting continental efforts in collaboration with AOSTI.

On a global scale, Africa’s engagement in the G20 has expanded, with the continent joining as a new member alongside the European Union (EU) and the 19 economies, with South Africa being the only African member holding the G20 Presidency in 2025, starting 2 December 2024, following Brazil (2024) and preceding the United States of America (US) for 2026. Additionally, Africa and the EU launched their 10-year joint AU-EU Innovation Agenda (2023-2032) in July 2023, as recommended by the AU-EU during a time when the United Nations General Assembly (UNGA) proclaimed the International Decade of Sciences for Sustainable Development (IDSSD) on 25 August 2023. This initiative focuses on measuring and promoting fundamental research, applied research and experimental development. The AU-EU Cooperation in Research and Innovation operates under the auspices of the AU-EU High-Level Policy Dialogue on Science, Technology and Innovation (HLPD-STI) since 2010. Both unions held their first AU-EU Research and Innovation Ministerial Meeting on 10 July 2020, which recommended a 10-year AU-EU Innovation Agenda aimed at translating Research and Innovation (R&I) into tangible positive socio-economic impacts. The joint AU-EU Innovation Agenda was officially launched in July 2023. Throughout these developments, the ASTII team actively participated in all AU-EU and G20 engagements, from the UNGA to the gatherings in India (G20, 2023) and Brazil.

The African Innovation Outlook series will continue providing an in-depth examination of the state of innovation across the African continent. We are setting the stage for the content, framing the series within the context of Africa's rapidly evolving innovation landscape, highlighting the continent's growing potential as a hub for creativity, technological advancement and business solutions to accelerate the African Continental Free Trade Area (AfCTFA).

Finally, as we are Energising Africa in using STI as one of the three pillars to create job and promote entrepreneurship in leveraging the youth, **we believe** in (i) **Africa's unique innovation ecosystem**; (ii) in **emerging trends** to move the 33 AU Member States from least developed to middle income countries by 2034; (iii) in **government and business/private sector engagement and global partnership** through innovation; (iv) in **the population as a catalyst** focusing on Africa's young population; (v) in **challenges and opportunities** in accelerating the Second Ten-Year Implementation of Agenda 2063; and (vi) in **global impact** as African innovations and emerging technologies are transforming the continent and influencing global markets through cross-border collaborations with Africa's innovative and homegrown solutions.

The 4th African Innovation Outlook (AIO) report provides context for the chapters focusing on individual sectors, case studies and countries contributing to the African innovation story.

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PREFACE

The African Innovation Outlook series is a programme developed under the Science, Technology and Innovation Indicators (ASTII) initiative, serving as an essential resource for understanding the innovation landscape across the African continent. In recent years, Africa has seen significant growth and development in the fields of science, technology and innovation (STI) within a national, regional and continental innovation system that involves various players and sectors. These sectors – business enterprises, government, higher education institutions, non-profit organisations and global partners – are increasingly recognised as vital for driving economic growth, enhancing quality of life and addressing the continent's unique challenges.

This fourth report provides a comprehensive analysis of the trends, patterns and progress made by African countries in STI, despite some limitations in data collection due to restrictions on field missions during the Covid-19 pandemic from 2020 to 2021. It examines key indicators that assess research and experimental development (R&D) investments, innovation, scientific publications, technology adoption and the broader policy environment, along with an overview of trade in the context of industrialisation. These insights aim to equip governments, policymakers, businesses and researchers with the data necessary to inform their decisions and strategies to enhance the continent's innovation ecosystem.

Innovation is essential for achieving the aspirations outlined in the African Union's Agenda 2063, which envisions a prosperous, integrated, knowledge-based and innovation-driven continent. The outlook serves not only as an analytical tool but also as a call to action for policymakers and stakeholders to prioritise innovation-driven development in alignment with existing continental frameworks and long-term visions. By fostering collaboration, strengthening human capital and investing in infrastructure, Africa has the potential to leverage STI for sustainable development and address critical challenges in health, agriculture, education and energy.

The path ahead presents both opportunities and challenges, such as accelerating the adoption of artificial intelligence, digitalisation, agricultural innovation and manufacturing, while also confronting issues like limited investment in research, low levels of digital infrastructure and the need for greater collaboration among businesses, educational institutions and government sectors. This outlook provides a roadmap for African nations to position themselves as global leaders in the knowledge economy by identifying gaps and leveraging their strengths.

The 4th African Innovation Outlook (AIO-IV) is a significant step toward unlocking the continent's STI potential and paving the way for a brighter, more innovative future for Africa. The next milestone will be the 5th AIO report (AIO-V), scheduled for release in early 2026.

The release of the AIO-2024 coincides with the farewell for the great performance of both H.E. Moussa Faki Mahamat, outgoing AUC Chairperson, H.E. Prof. Gaspard Banyankimbona, outgoing Commissioner of AUC-ESTI and Professor Aggrey Ambali, who led AUDA-NEPAD STI programmes for almost two decades. Theirs is a legacy of leadership within the African Union (AUC and AUDA-NEPAD), underscoring a commitment to advancing science, technology and innovation across Africa.

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The African Union Development Agency (AUDA-NEPAD) wishes to express its deep gratitude to its Office of Science, Technology and Innovation (OSTI) and the ASTII Programme, including the African Union Commission (AUC), for making possible the drafting of this 4th AIO report (AIO-2024). The contribution of the African Observatory of Science, Technology and Innovation (AOSTI) was very positive by involving the Egyptian STI Observatory, which operates within the Academy of Scientific Research and Technology of Egypt, with the chapter on bibliometrics. The collaboration between various African Union institutions helps to speak with one voice to support the implementation of flagship programmes aimed at transforming the continent.

The contributors and reviewers involved in this STI measurement report come from various institutions and countries with a very rich past in the field of STI indicators and related policies. Their names are well listed at the bottom, some of them representing their institutions and others based on their expertise of more than 10 years in national and international systems for leading the measurement of research and innovation.

Also, it will be difficult to forget the sacrifices and dedication of late Prof. Claes Brundenius of Sweden and Mr. Filipo Zulu of Zambia. The entire STI measurement community will remember them for the role they played in advancing STI measurement for evidence-based decision making and policy development.

Sweden, being a traditional and long-term partner of the ASTI programme, has supported the activities since 2007 to the point that the impact has pushed AUDA-NEPAD to develop the AU-EU Innovation Agenda. This latest development is required to align the measurement in Africa supported by STISA-2024 to the 2030 Agenda (Sustainable Development Goals, SDGs) through SDG-9 and SDG-17. The latter is related to international partnership as it involves Swedish, Brazilian and UK institutions. The involvement of Lund University since 2007 to date (4th phase) allowed Sweden to secure scholarships for a two-month postgraduate module on *transformation, innovation and resilience for sustainable development*, allowing African delegations to share their experiences in Sweden as part of the African Union-European Union (AU-EU) engagement. Through the Foreign, Commonwealth and Development Office (FCDO), a Ministerial Department of the Ministry of Foreign Affairs (MRE) and the Brazilian Cooperation Agency (ABC), Brazil's leading development co-operation entity at the Ministry of Foreign Affairs, the UK-Brazil-Africa Trilateral Development Cooperation (TDC) brought SDG17 to SDG9 into ASTII, initially managed by both AUDA-NEPAD and Sweden for the past 18 years.

Furthermore, the role played by the Swedish International Development Cooperation Agency (Sida) has been impactful because of the continuous follow-ups and supervision of the grants by Dr Claes Kjellström, Mr Daniel Tiveau and Dr Pernilla Sjöquist Rafiqui, whose support has allowed the expansion of the AU/ASTII programme to be a monitoring, evaluation and learning project of the 10-year AU-EU Innovation (2023-2032). It also applies to the role that the ASTII team plays in some G20 meetings in both the Research and Innovation Working Group (RIWG) and the Education Working Group (EdWG), including the G20 think tanks platform (Think20 or T20).

The production of this report is also a sign of a strong collaboration between AUDA-NEPA and the then ASTII Faculty today, known as the ASTII Technical Committee cand omprising resource persons representing entities such as the Global Innovation Index (GII) of the World Intellectual Property Organ isation (WIPO), Lund University, South Africa's Centre for STI Indicators Centre (CeSTII), University of Pretoria (UP), University of Johannesburg (UJ), Tshwane University of Technology (TUT), the United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-Merit), some key African STI Think Tanks such as the Science, Technology and Innovation Policy Research Organ isation (STIPRO) in Tanzania and the African Centre for Technology Studies (ACTS) in Kenya. This includes AOSTI and independents who supported their countries (Senegal and South Africa) joined by experts from Benin, Nigeria, Ghana and the Institute for Security Studies (ISS) as contributors to the drafting of this Fourth Africa Innovation

Outlook (AIO-2024) Report. Their expertise, commitment and dedication were essential for the real isation of this work and we plan to resume the editorial assignment of the next report (AIOI-2025) to be launched in 2026. The ASTII-Phase 4 teams at both AUDA-NEPAD and Lund University have been hyperactive throughout various training workshops and postgraduate modules held in Africa and Sweden and directly or indirectly supporting the first deliverable of 2022-2025: Prof. Martin Andersson, Mrs Maria Flores, Mrs Ida Burguete Holmgren, Mr Andreas Bryngelson, Dr Linn Ternsjö, Natassjha Venhammar, Dr Clara Dallaire-Fortier, Mrs Zipho Sexwale, Mr Pagal Agbanglanon and Mr Lukovi Seke.

Moreover, we would particularly like to thank the countries that submitted their research and development (R&D) and Innovation datasets duly validated and endorsed by their respective institutions in charge of research statistics (national Statistics Offices: NSO). Our willingness to sustains the official duty of working with national experts from various ASTII focal points requires regular monitoring at a time when it is urgent to mobilise resources to support countries facing budgetary constraints. This reminds challenges experienced by the UNESCO Institute of Statistics (UIS, Montreal) affected by the withdrawal of members' support affecting the consolidation of efforts at the global level in the compilation of STI indicators from the 193 countries.

A big thank-you to the financial and technical partners at the national, regional, continental and international levels, whose unwavering support at the national and regional levels made possible the production of this report and the sustainability of the ASTII institutional focal points. Their commitment to supporting innovation in Africa as a driver for the future of our economic and social development is part of a national obligation and responsibility reported during annual or biennial ministerial statutory gatherings at the regional and continental levels.

Finally, we hope that this report will contribute to fuelling reflections and actions aimed at promoting innovation and R&D in Africa, for the benefit of future generations and to accelerate the Second Ten-Year Implementation Plan (STYIP) of Agenda 2063. We thank all the directors, supervisors and heads of division of AUDA-NEPAD who supported the ASTII Programme, mainly Madam Estherine Fotabong, Mr Symerre Grey-Johnson, Prof. Aggrey Ambali, Dr Tichaona Mangwende and Dr Justina Dugbazah, during the review of the institutional structure, which allowed the definitive positioning of the ASTII Programme in the office of the Chief Executive Officer (CEO). The legacy of previous coordinators involved on the ASTII Advisory Group, namely Prof. Philippe Kuhutama Mawoko and Prof. Luke Evuta Mumba, is tremendous in always being ready to help not only in the first and second AIO reports but throughout all drafting processes to date. The role played by the former CEO, H.E. Dr Ibrahim Assane Mayaki and the vision of the current CEO, H.E. Nardos Bekele-Thomas, converge to keep the ASTII programme as a robust instrument to inform the design of policies based on the evidence it produces, in addition to the synchronisation of activities with AOSTI and AUC in addition to RECs.

CONTRIBUTORS TO THE 4TH AIO REPORT

The fourth edition of the African Innovation Outlook (AIO-4) was developed under the leadership of H.E. Nardos Bekele-Thomas, the CEO of the African Union Development Agency (AUDA-NEPAD). The project was partially supervised by Prof. Aggrey Ambali, the former Head of Science, Technology and Innovation (STI) until April 2024, followed by Dr. Msingathi Sipuka, the Chief of Staff and interim Head of STI until December 2024 and the incoming Head of STI, Prof. Brando Okolo, who will take over on January 31, 2025.

The report was coordinated by the ASTII-4 project team, with direct and ongoing technical support from the ASTII Technical Advisory Group, led by Prof. Luke Mumba, the former ASTII Coordinator from 2012 to 2016.

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ACRONYMS

4IR	4th Industrial Revolution
AAS	African Academy of Sciences
ACTSAfrican	Centre for Technology Studies
AfCFTA	African Continental Free Trade Area
AfDB	African Development Bank
AFI	African Futures & Innovation Programme
AI	Artificial Intelligence
AIO	African Innovation Outlook
AMCOST	African Ministerial Conference on Science and Technology
AMU	Arab Maghreb Union
ANRSA	Agence Nationale de la Recherche Scientifique Appliquée
AOSTI	African Observatory of Science, Technology and Innovation
APRM	African Peer-Review Mechanism
ASTII	African Science, Technology and Innovation Indicators
AU	African Union
AUC	African Union Commission
AUDA-NEPAD	African Union Development Agency-NEPAD
AU-EU	African Union – European Union
BERD	Business Expenditure on R&D
BMGF	Bill and Melinda Gates Foundation
BUS	Business Enterprises
CEMAC	Central African Economic and Monetary Community
CEN-SAD	Community of Sahel-Saharan States
CESA	Continental Education Strategy for Africa
CeSTII	Centre for Science, Technology and Innovation Indicators Centre
CIA	Central Intelligence Agency
CIS	Community Innovation Survey
COMEDAF	Conference of Ministers of Education of the African Union
COMESA	Common Market for Eastern and Southern Africa
CPO	Consolidated Plan of Action
DMC	Minimum symmetric data coverage criteria
DST	Department of Science and Technology
EAC	East African Community
EAPP	East African Power Pool
EC	European Commission
ECCAS	Economic Community of Central African States
ECI	Economic Complexity Index
ECOWAS	Economic Community of West African States
EST	Education, Science and Technology
ESTIO	Egyptian STI Observatory
EU	European Union
Eurostat	European Statistical Office
FDI	Foreign Direct Investment
FM	Frascati Manual
FoRD	Field of R&D

FTE	Full-time equivalent
FWCI	Field-Weighted Citation Impact
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on R&D
GII	Global Innovation Index
GOV	Government
GOVERD	Government Expenditure on R&D
GVC	Global Value Chains
HC	Headcount
HE	Higher Education
HERD	Higher education expenditure on intramural R&D
HLPD	High-Level Policy Dialogue
HRST	Human Resources Science and Technology
HSRC	Human Sciences Research Council
I&D	Innovation and Development
ICT	Information and Communication Technology
IDRC	International Development and Research Centre
IDSSD	International Decade of Sciences for Sustainable Development
IERI	Institute for Economic Research on Innovation
IFPRI	International Food Policy Research Institute
IGAD	Intergovernmental Authority on Development
IGs	Intermediate Goods
ILO	International Labour Organisation
IoT	Internet of Things
IP	Intellectual Property
IPR	Intellectual Property Rights
ISCED	International Standard Classification of Education
ISI	International Statistical Institute
ISIC	International Standard Industrial Classification
ISS	Institute for Security Studies
ISS	Institute for Security Studies
LCU	Local Currency Unit
LDCs	Least Developed Countries
LUCE	Lund University Commissioned Education
M&E	Monitoring and Evaluation
MNC	Multinational Corporation
MVA	Manufacturing Value Added
NEC	Not Elsewhere Classified
NEPAD	New Partnership for Africa's Development
NESTI	National Experts on Science and Technology Indicators
NPCA	NEPAD Planning & Coordinating Agency
NSI	National Statistical Institute
NSO	National Statistics Offices
NSTC	National Science and Technology Council
OAU	Organisation of African Unity
OECD	Organisation for Economic Co-operation and Development
OM	Oslo Manual
PNP	Private Non-Private
PNPERD	Private Non-profit Expenditure on R&D
PPP	Purchase Power Parity

PPP$	Purchase Power Parity (International dollar)
R&D	Research and Experimental Development
REC	Regional Economic Communities
RI	Research intensity
RPI	Research Policy Institute
RSA	Republic of South Africa
S&T	Science and Technology
SADC	Southern African Development Community
SciVal	Web-based Elsevier-Scopus data analytics tool for research output performance
SDG	Sustainable Development Goals
SET	Scientists, Engineers and Technologists
SGCI	Science granting councils' initiative
SHaSA	Strategy for the Harmonisation of Statistics in Africa
Sida	Swedish International Development Cooperation Agency
SMEs	Small and Medium-sized Enterprises
SNA	System of National Accounts
STC-EST	Specialised Technical Committee on Education, Science and Technology
STEM	Science, Technology, Engineering and Mathematics
STG	Specialised Technical Group
STI	Science, Technology and Innovation
STIPRO	Science, Technology and Innovation Policy Research Organisation
STISA	Science, Technology and Innovation Strategy for Africa
STYIP	Second Ten-Year Implementation Plan
TDC	Technical Development Cooperation
TUT	Tshwane University of Technology
UIS	UNESCO Institute of Statistics
UJ	University of Johannesburg
UNU-MERIT	United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology
UP	University of Pretoria
WIPO	World Intellectual Property Organisation

EXECUTIVE SUMMARY

The expansion of Science, Technology and Innovation (STI) is pivotal in accelerating Africa's industrialisation, providing the foundation for sustainable economic growth, technological progress and regional development. This expansion is well-rooted in several frameworks, notably the African Union's Agenda 2063, which emphasises Africa's transformation into a knowledge-driven economy. Below is an in-depth analysis of STI's role in promoting industrialisation in Africa, including its challenges and the actionable recommendations to address them.

The **African Innovation Outlook IV (AIO 2024)** builds on the efforts initiated since 2007 to accelerate Africa's industrialisation through science, technology and innovation (STI). The ASTII initiative, launched by the African Union (AU), aims to enhance STI measurement and capacity-building among Member States to inform evidence-based policy development. This report presents the progress, challenges and opportunities within the STI landscape across Africa, focusing on industrialisation, research and experimental development and innovation.

The report underscores the growing role of **technological innovation** as a driver of industrialisation in Africa. It highlights key areas such as:

- **Manufacturing and Infrastructure**: Africa's industrialisation progress is uneven, with North and Southern Africa leading in manufacturing development. However, the continent remains the least industrialised globally, largely due to infrastructure gaps, inadequate financial inclusion and limited value-added activities in the manufacturing sector
- **Digital and Technological Transformation**: Digital technologies, including mobile tech, some emerging technologies, among which 3D printing, Artificial intelligence and fintech, are rapidly reshaping Africa's economic landscape, fostering innovation in agriculture, education and public services
- **Renewable Energy**: Africa's investment in renewable energy, particularly solar and wind, is recognised as critical to overcoming energy deficits and promoting sustainable industrial growth

The status of Research and Development (R&D) in Africa is characterised by progress but also significant challenges. The continent's R&D initiatives are concentrated in a few countries, with South Africa, Egypt, Kenya and Nigeria leading the way. These countries are investing in key sectors like agriculture, health, information and communication technologies (ICT) and energy, addressing local and regional challenges such as food security, infectious diseases and climate change.

Despite these advancements, the overall investment in R&D remains low. Africa contributes less than 1% to global R&D expenditure and the average expenditure on R&D as a percentage of GDP in most African countries is well below the global average of 2%. There is a shortage of researchers, limited infrastructure and low levels of private sector investment. Collaboration with international partners, governmental and non-governmental organisations and the establishment of innovation hubs are helping mitigate some of these challenges. Initiatives like the African Union's STISA-2024 are driving strategic efforts to strengthen research across the continent.

Africa continues to face numerous challenges in its industrialisation journey, including:

- **Infrastructure deficits:** limited access to reliable energy, transportation and communication infrastructure continues to constrain industrial development
- **Human capital and skills gaps:** the lack of skilled labour and inadequate investment in education and technical training impedes the continent's ability to drive innovation and industrialisation
- **Financial and institutional barriers**: limited access to financing and governance issues, including corruption and political instability, hinder the growth of industries and innovation sectors

The AIO 2024 stresses the need for enhanced coordination between **African governments, regional economic communities (RECs)** and international partners. Key recommendations include:

- **Strengthening national innovation systems:** governments must focus on enhancing research and innovation capacities by investing in education, infrastructure and entrepreneurship and supporting the stakeholders in the NSI
- **Leveraging international partnerships:** global partnerships should be fostered to promote knowledge transfer, technological adoption and financing for industrialisation and intra-African partnerships for country complementarity
- **Sustainable industrial policies:** AU Member States are encouraged to align their industrialisation and STI policies to accelerate the implementation of the **African Union's Agenda 2063** for inclusive and sustainable economic growth
- **Increase investment in R&D:** AU Member States need to intensify national commitment towards increasing R&D spending as a percentage of GDP. Public-private partnerships are encouraged to boost R&D funding
- **Enhance capacity building:** more investment in education and training is crucial to develop skilled researchers and innovators. Strengthening STEM (Science, Technology, Engineering, Mathematics) education and providing incentives for research careers, especially among young Africans, are necessary
- **Promote regional cooperation:** pan-African initiatives and regional collaborations should be strengthened to promote knowledge exchange, joint research projects and the sharing of resources, particularly for cross-border challenges like health, climate change and food security
- **Strengthen innovation ecosystems:** governments are encouraged to support tech hubs, innovation centres and incubators, which have been thriving in some African cities. Policies that encourage startups, entrepreneurship and research commercialisation can help bridge the gap between research and practical application
- **Encourage private Ssctor participation:** tax incentives, grants and policy reforms need to be considered by increasing the involvement of the private sector in R&D activities
- **Leverage digital technology:** invest in digital infrastructure to enhance research capabilities, offering Africa a chance to leapfrog into advanced research areas
- **Increase data availability and quality:** develop a culture of data collection, analysis and dissemination for evidence-based decision-making processes by strengthening relevant national, regional and continental bodies
- **Link STI policies to industrialisation:** put in place policies that promote local products and support local industries and SMEs and develop import substitution strategies to promote local industries

Additional recommendations **for strengthening industrialisation through smart manufacturing:**

- **Develop smart factory demonstrators and pilot lines:** establish national and regional demonstration facilities to showcase Industry 4.0 technologies (automation, robotics, AI, IoT, 3D printing), enabling SMEs to test, learn and adapt them cost-effectively
- **Foster industrial digital skills:** design specialised training programmes on smart manufacturing, digital twins, additive manufacturing and advanced process control to address Africa's skills gap and prepare the next generation of industrial leaders
- **Promote local manufacturing innovation hubs:** encourage clusters where universities, industries and start-ups collaborate to design, prototype and scale industrial solutions tailored to local contexts, with an emphasis on affordable and resource-efficient technologies
- **Encourage technology transfer for industry 4.0:** facilitate structured partnerships with international firms and research institutions to accelerate the adoption of advanced manufacturing technologies while ensuring adaptation to Africa's specific realities
- **Support SMEs in industrial upgrading:** create targeted financing and advisory schemes to help SMEs gradually transition from traditional production methods to smart, data-driven and sustainable manufacturing processes
- **Embed sustainability in smart manufacturing:** encourage the use of renewable energy, circular economy practices and eco-design in industrial upgrading projects to ensure industrialisation is both competitive and sustainable

CONCLUSION

While Africa has made significant strides in STI development, there remains a need for targeted efforts to overcome industrialisation barriers. The African Innovation Outlook 2024 (AIO-2024) report emphasises the critical role of STI in driving Africa's industrial transformation, with a call to action for stronger policy frameworks and investments to harness the continent's vast potential. The AIO-2024 report underscores Africa's ongoing journey towards sustainable industrialisation through Science, Technology and Innovation (STI). Despite significant progress made through initiatives such as the AUDA-NEPAD/ASTII and AOSTI for the joint publication of AIO reports, challenges remain in the areas of infrastructure development, financing and human capital enhancement to drive economic growth and development.

The AIO-2024 report calls for a collaborative effort among governments, academia, industry and international partners to realise the continent's industrialisation goals. The task is formidable, but with collective will and strategic action, Africa can achieve sustainable growth and transformation through innovation and technology. The status of Research and Development (R&D) in Africa is characterised by progress but also significant challenges. The ASTII programme, which was launched in 2007 and reached up to 23 participating countries in AIO-2019, has recorded only 12 countries submitting R&D dataset in the AIO-2024 showing a first ever sharp decline of 48% compared to the 3rd AIO report (AIO-2019). This post-Covid-19 decline can be attributed to lack of dedicated institutions and national budget to sustain surveys in most countries. The continent's R&D initiatives are concentrated in a few countries, with Egypt, Rwanda and South Africa, leading the way. These countries are investing in key sectors such as agriculture, health, information and communication technology (ICT) and energy, addressing local and regional challenges such as food security, infectious diseases and climate change.

CHAPTER 1
INTRODUCTION

1.1 STRUCTURE OF THE 4TH AFRICAN INNOVATION OUTLOOK REPORT (AIO-2024)

The report on Science, Technology and Innovation (STI) in Africa provides a comprehensive overview of the continent's industrialisation efforts, emphasising the critical role of STI in achieving sustainable growth. It highlights key challenges, such as infrastructure gaps and the need for more investment in research and development (R&D), while also pointing to opportunities for leveraging digital technologies, public-private partnerships and regional synergies. This section provides a concise summary of each chapter, focusing on core insights and statistics.

Chapter 1: Introduction

This chapter introduces the African Science Technology and Innovation Indicators (ASTII) programme, tracing its evolution from 2007 to 2023. The ASTII initiative was launched to harmonise the collection of STI data across African countries, ensuring that evidence-based policy development can drive industrial growth. The programme has been instrumental in helping countries like Egypt, Rwanda and South Africa build STI capacity through training, data collection and analysis. These efforts are aimed at supporting Africa's broader industrialisation goals by establishing a reliable foundation for measuring progress in STI.

Chapter 2: Industrialisation, Innovation and Development in Africa

This chapter explores the factors driving innovation and industrialisation in Africa, emphasising regional efforts to enhance local manufacturing capacities. The African Union (AU) and its Member States have made regional industrial hubs a priority to accelerate economic transformation, focusing on sectors such as agro-processing, textiles and information technology. The report highlights the urgent need for increased investment in infrastructure, especially in transportation and energy, to support industrial growth.

Countries such as Rwanda, Egypt and South Africa are noted for their progress in aligning science, technology and innovation (STI) policies with their national development plans. However, data from this chapter indicates that many African nations still face significant challenges, including underdeveloped manufacturing sectors and inadequate infrastructure. To address these obstacles, countries must concentrate on improving the implementation of STI, fostering entrepreneurship, boosting foreign direct investment (FDI) and embracing digital and eco-friendly technologies.

Chapter 3: Africa's STI Landscape

This chapter analyses Africa's STI landscape, focusing on economic and human development challenges. It emphasises the Gross Domestic Expenditure on R&D (GERD), with Egypt and Rwanda leading the continent at 1.02% and 0.79% respectively of GDP and South Africa following at 0.62%. These figures highlight the uneven distribution of R&D investment across the continent, with most countries investing less than 1% of GDP in research. For example, Rwanda's GERD is 0.79%, which, although smaller in per capita terms, reflects its growing focus on innovation-driven development. In addition to GERD, the chapter discusses the importance of human capital development, particularly in the fields of Science, Technology, Engineering and Mathematics (STEM). Countries such as Egypt, which reports 343 198 R&D personnel and South Africa with 8 560 personnel, show significant engagement in research activities. However, the participation of women in R&D remains low, underscoring the need for policies that promote gender inclusivity in scientific research.

Chapter 4: Accelerating Industrialisation Through STI Policies

Chapter 4 highlights the role of Regional Economic Communities (RECs) in accelerating industrialisation through coordinated STI policies. It discusses the importance of harmonising national policies with regional frameworks, such as the Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024). By fostering public-private partnerships and improving policy coherence, African nations can leverage their collective resources to drive innovation and industrial growth.

The chapter also emphasises the importance of building industrial ecosystems that are regionally integrated, allowing countries to specialise in key sectors and create synergies that boost competitiveness across borders. Key recommendations include strengthening infrastructure development, improving digital connectivity and adopting best practices from successful economies.

Chapter 5: Research and Experimental Development

This chapter delves into the state of Research and Experimental Development (R&D) in Africa, showcasing key statistics on R&D expenditure and personnel. For instance, Egypt leads with 1.02% GERD, which translates to $153.93 per capita, followed by both Rwanda (0.79%) and South Africa (0.62% and $90.52 per capita), which represents a growing commitment to R&D, particularly in higher education and government research institutions. R&D personnel data reveals that Egypt employs 343 198 people in R&D, with the majority in higher education, while South Africa has 8 560 R&D professionals. The participation of women in R&D remains limited, highlighting the need for increased efforts to close the gender gap in research fields. The report stresses the importance of scaling up investments in R&D, particularly in underfunded sectors such as healthcare, agriculture and engineering.

Chapter 6: Innovation and Emerging Issues

This chapter examines Africa's performance in innovation, drawing on evaluations from the Global Innovation Index (GII). Countries such as South Africa, Kenya and Morocco are at the forefront of innovation rankings, showcasing strong achievements in areas like digital technology adoption and the development of startup ecosystems. However, Africa's contribution to global high-tech exports is still relatively low, with Tunisia and Morocco accounting for 4.46% and 2.14% of high-tech exports, respectively.

The chapter underscores the importance of adopting emerging technologies such as Artificial Intelligence (AI), Internet of Things (IoT) and advanced manufacturing to enhance Africa's industrial competitiveness. It calls for increased investment in digital infrastructure and the creation of innovation-friendly regulatory environments to foster the growth of tech-driven industries.

Chapter 7: Bibliometric Analysis

The final chapter presents a bibliometric analysis of scientific production in Africa from 2008 to 2022. It highlights that countries like Egypt, South Africa and Nigeria are leading contributors to scientific research on the continent, particularly in fields like natural sciences and engineering. The report also notes that collaboration between African countries and international research institutions has grown steadily over the years, with increasing co-authorship in scientific publications.

The analysis underscores the importance of continued investment in scientific research and the development of institutional frameworks that support collaborative research efforts across borders. By improving access to research funding and fostering regional research networks, African countries can boost their scientific output and contribute to global knowledge economies.

Recommendations and Conclusion

This report offers a comprehensive overview of Africa's journey toward industrialisation through STI, R&D and innovation. While progress has been made, significant challenges remain, including uneven R&D investment, limited infrastructure and low female participation in research. However, countries like Egypt, South Africa and Rwanda are emerging as leaders in driving scientific innovation and industrial development. With continued focus on policy reform, regional collaboration and investment in human capital, Africa can unlock its potential for sustainable growth and become a key player in the global economy.

1.2 THE ASTII JOURNEY: 2007 TO 2023

The need for coordination in Science, Technology and Innovation measurement in Africa became evident during the first Meeting of the African Inter-Governmental Committee on Science, Technology and Innovation (STI) Indicators held in Mozambique in 2007. This meeting marked the launch of the African Science, Technology and Innovation Indicators (ASTII) initiative. The initiative aimed to establish the African Observatory of Science, Technology and Innovation (AOSTI) in a short time frame. Additionally, it contributed to the sustainability of a capacity-building mechanism for STI measurement exclusively coordinated by the ASTII Programme at AUDA-NEPAD for African Union (AU) Member States. This achievement is a significant legacy of the African Ministerial Conference on Science and Technology (AMCOST) and its subsequent Bureaus, which represent all AU regions. Currently, these entities have merged with the Conference of Ministers of Education of the African Union (COMEDAF) and now operate as the Specialised Technical Committee on Education, Science, Technology and Innovation (STC-ESTI).

In November 2003, African countries endorsed the development of indicators for scientific research, technological development and innovation activities during a meeting of ministers in Johannesburg, South Africa. Subsequently, from September 17 to 18, 2007, the African Inter-Governmental Committee on Science, Technology and Innovation (STI) convened in Maputo, Mozambique. This meeting aimed to accelerate the commitments made by the ministers, with a mandate to: (i) promote a better understanding of national and regional science and innovation systems among African countries; (ii) enhance skills for reviewing and developing STI policies; and (iii) improve the quality of STI initiatives.

The initial technical work of ASTII started with an Experts Working Group on STI indicators in 2005 [2]. The collection and analysis of STI data to produce internationally comparable indicators is critical to assess the levels of investment in research and development (R&D) and innovation, in addition to the bibliometrics analysis.

The measurement of STI performance is taking shape at the AU level through AOSTI and AUDA-NEPAD but also regional economic communities (RECs), including at the national level where the ASTII has been progressively institutionalised with ASTII focal points becoming national observatories (Egypt, Sudan, Kenya, Eswatini) or fully-flagged councils (Rwanda, Malawi) and commissions (Kenya, Namibia, etc.) having the mandate to develop and revise policies based on evidence. So far, ministries in charge of STI and the National Bureaus of Statistics in Member States have been involved, so that more than 3,500 African experts have been trained since 2007.

The ASTII programme at AUDA-NEPAD has sustained training to conduct STI surveys and coordinate the consolidation of datasets published at the continental level as part of the African Innovation Outlook (AIO) series.

The first AIO Report was published in 2010 (AU-NEPAD, 2010), the second report in 2014 (NPCA, 2014), the third in 2020 (AUDA-NEPAD, 2019) and this fourth report scheduled for a release on 14 February 2025 (AU Assembly side event in Addis-Ababa) because of the late submission by ASTII participating countries in 2023/2024. Regional economic communities (RECs) are not left behind in the production of their trend on Research and Innovation (R&I) performance expected by ministers during regional statutory conferences in addition to the importance of ASTII indicators helping in evidence-based policy development.

Many SADC Member States are conducting annual Research and Development (R&D) surveys along with biennial Innovation surveys. These surveys aim to evaluate the performance of their national innovation systems, track the growth and composition of R&D expenditures and assess the number of human resources involved in R&D activities. From 2007 to 2014, the STI measurement in Africa has been implemented through the ASTII programme in two consecutive phases (2007-2010 and 2011-14) in collaboration with members of its faculty representing UNU-MERIT, Lund University, UNESCO Institute for Statistics, the African Development Bank (AfDB), IFPRI on Agricultural Science and Technology Indicators (ASTI) and countries such as Tunisia and South Africa, respectively through their Observatory and Human Sciences Research Council's Centre of Science, Technology and Innovation Indicators (HSRC/CeSTII). The ASTII programme participated in preparatory meetings for the implementation of the 12th Ordinary Session Decision Assembly/AU/Dec.235 (XII) of February 2009 on AOSTI and its operationalisation through the Decision Assembly/AU/Dec.452 (XX) of January 2013.

It is important to emphasise that the first phase (2007-2010) was a proof of concept, demonstrating that participating countries could be trained in the use of common survey questionnaires, analysis and the production of indicators. Only the 19 countries involved in the African Peer Review Mechanism (APRM) were part of this phase. During this period, ASTII has encouraged African Union (AU) Member States to start developing science, technology and innovation (STI) indicators. It has enabled some countries to begin conducting research and experimental development (R&D) and innovation surveys and to build national indicator capacities to inform STI policy formulation and review. AU Member States have made progress in enhancing knowledge and understanding of the value of STI indicators and are moving towards institutionalising ASTII through national focal points.

From 2015 to 2019, the ASTII Programme was implemented through the then NEPAD Planning and Coordinating Agency (NPCA) in collaboration with AOSTI and the United Nations Economic Commission for Africa (UNECA). It managed four work packages to ensure its alignment with the Strategy for the Harmonisation of Statistics in Africa (SHaSA), aiming to roll out initiatives with both the AU Commission and the Association for the Development of Education in Africa (ADEA) via the African Union (AU) Specialised Technical Group (STG) on Education, Science and Technology (EST) Statistics. The first AU-STG-ESTI meeting was held in South Africa from 13-15 February 2017. This set-up is also like the SADC Reference Group on STI Statistics to make sure that STI becomes part of the SADC Statistics Yearbook after being endorsed by Statisticians-General and Ministers of National Economy and Planning. The second phase involved more countries and continued to refine the capacity building needed to produce indicators. ASTII Phase 3 focused on four work packages, namely (i) the Continental Web-Based Data Platform for Education and STI Indicators; (ii) the traditional set-up of strengthening and consolidating the collection and analysis of data to produce STI indicators expanded to the Science granting councils initiative (SGCI); (iii) to increase R&I indicators Knowledge and awareness in AU Member States through the STG-ESTI to regularly updating STIC-ESTI; and (iv) the Development of Tools to Assess and Measure the Potential of AU Member States to Innovate with a segment Monitor and Track the development of STI Policies in Africa. The Covid period helped the ASTII Team to manage the Bill and Melinda Gates Foundation (BMGF) funded project on countdown, focusing on priority-setting in support of the African Academy of Sciences (AAS).

Thus, the third phase sustained the process of building capacity and considered extending the initiative to develop statistical indicators directly relevant to Africa. Examples included using a broad definition of innovation that applies across all economic sectors to examine innovation in government and higher education, as well as in business. It also covered innovation in the informal economy and the impact of social innovation in African countries. In all cases, a key outcome of measurement and indicator production was support for the development of policy and the monitoring and evaluating policy that has been implemented by AUDA-NEPAD through the ASTII programme in addition to the African Observatory of Science, Technology and Innovation (AOSTI) as recommended in the seventh chapter of the Science, Technology and Innovation Strategy for Africa, STISA-2024 (AUC, 2015:48-51). In an ideal environment, evaluation leads to policy learning and strengthens capacity building.

Finally, the fourth phase from 2021 to 2025 funded by the Swedish International Development Agency (Sida) in addition to AU Member States has attracted the UK and Brazil to develop a pilot under the UK-Brazil-Africa Technical Development Cooperation (TDC) on data management, as nexus between Sustainable Development Goals 9 and 17 on “Infrastructure, Innovation and Industrialisation” and “International Partnerships for sustainable development” to overcome the lack of data for real-time decision that affected quick actions during the Covid-19 pandemic. While tracking the STISA-2024 target of 1%, ASTII in its fourth phase is implemented through a consortium comprised by Tshwane University of Technology (TUT), via its UNESCO Chair in Innovation and Africa Integration within the Institute of Economic Research and Innovation (IERI), Lund University Commissioned Education (LUCE) and the AUDA-NEPAD.

The 4th phase of the African Science, Technology and Innovation Indicators (ASTII) initiative addresses important policy issues relevant to Africa and aims to ensure the long-term sustainability of the programme. This phase is also aligned with the Science, Technology and Innovation Strategy for Africa 2024 (STISA-2024) and supports the goals outlined in Agenda 2063, as well as specific targets in the 2030 Agenda, particularly target 9.5 concerning infrastructure, innovation and industrialisation https://nepad-my.sharepoint.com/personal/lukovis_nepad_org/Documents/Documents/2021/Afrilook ASTII_Phase4/ASTII Proposal 2022-25 FIRST DRAFT_27052021.docx.The overall objective remains largely the same as the ministerial decisions but focuses on improving science, technology and innovation (STI) measurement among least developed countries (LDCs) and those with limited visibility in STI. This alignment aims to support policy development in accordance with regional and continental STI frameworks, as well as the 2030 Sustainable Development Goals (SDGs).

The sub-objectives designed to achieve the overall goal focus on (i) enhancing national and regional expertise to support the production of research and development (R&D) and innovation indicators for policy development and monitoring in at least 40 African Union Member States and 5 regional economic communities (RECs) by 2025; (ii) formalising the ASTII community of best practice of almost 80 African officials (Alumni) by 2025 through collaboration with institutions in the Swedish Innovation System. This is handled through a postgraduate module on transformation, innovation and resilience for sustainable development. The ASTII Phase 4 Scholarship scheme funded by Sida are provided for senior experts well engaged in STI measurement so that they could gain the big picture of the subject and be able to provide informed guidance at a high level; (iii) informing African countries on the state of STI in the continent on measurement and policies in alignment to AU STG-EST; and (iv) exploring emerging measurement issues such as the informal sector, innovation beyond the business sector, to improve the understanding of STI national landscape.

In conclusion, it is important to emphasise the significance of STI indicators in an African context, which began with the launch of the ASTII initiative.

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CHAPTER 2
INDUSTRIALISATION, INNOVATION AND DEVELOPMENT IN AFRICA

2.1 BACKGROUND

Industrialisation refers to the broad process through which an economy diversifies and strengthens its productive base, moving beyond reliance on subsistence activities and low value-added sectors toward more complex, technology-enabled and large-scale production of goods and services. It is not limited to manufacturing but extends across multiple domains such as agriculture, mining, energy, logistics and infrastructure, integrating innovation, mechanisation and new organisational models. Industrialisation drives structural transformation by increasing productivity, creating jobs, expanding value chains and fostering economic resilience.

It involves:

- The introduction of advanced machinery, automation and digital technologies across sectors
- The rise of industrial clusters, factories and service hubs that add value to raw materials and support regional development
- Increased production capacity, efficiency and competitiveness, enabling economies to meet local demand and participate in global markets
- Workforce transformation through the development of new technical skills and the migration from informal and rural activities into formal, urban and technology-driven employment

Examples across sectors include:

- **Agriculture:** mechanisation of farming, agro-processing industries and digital agriculture platforms that transform raw produce (e.g. cocoa, maise, cassava) into higher value products such as food ingredients, beverages and bio-based materials
- **Mining:** transition from raw mineral extraction to beneficiation and local processing (e.g. refining bauxite into aluminium, polishing gemstones, producing battery-grade lithium from African reserves)
- **Logistics:** development of integrated transport corridors, ports and smart supply chain systems, including digital tracking, warehousing and cold-chain logistics to support trade and industrial exports
- **Infrastructure:** expansion of industrial parks, special economic zones, energy and water infrastructure and digital connectivity to support business growth and attract investment
- **Energy:** building renewable energy industries (solar panel assembly, wind turbine components, biomass power plants) and improving access to reliable power for industries and communities

Key characteristics of industrialisation include:

- The systematic development and use of machinery, automation and smart technologies
- The emergence of factories, processing plants and industrial clusters
- Expansion of value chains and greater output in both goods and services
- Economic diversification, moving beyond raw resource extraction toward value-added industries
- Shifts in workforce skills and geography, with growing demand for STEM-based competencies and urban industrial employment

Over the years, African leaders have restated their determination to seise emerging opportunities to foster industrial development as an effective, socially responsible and sustainable means towards economic transformation (AU, 2022). Many African countries have then experienced an unprecedented growth rate, partly linked to a “commodity-boom” and partly due to sound economic governance. Nevertheless, there has been a subdued industrial supply response to several years of macroeconomic stability. This is largely attributed to several supply-side constraints, such as the lack of necessary industrial capacities and capabilities; inadequate entrepreneurship and institutional support; energy and infrastructure bottlenecks and demand constraints due to the low purchasing power of most of the population; and a low aggregate demand from the public sector (AU, 2022). Supply-side constraints also existed and continue to exist outside the manufacturing sector. A lagging agricultural sector has constrained industrial production and competitiveness in many countries due to an inadequate or irregular supply of the requisite agricultural inputs and the impact of climate change. This, in turn, has constrained the growth of manufacturing based on agro-products or processing. Although challenges persist, none of them is insurmountable. The ever-diversifying global economy and its industrial value chains and the growth of industrial dynamism in the South create as many opportunities for participation as they produce new challenges. Most importantly, they create an urgency to act decisively by strengthening local capacities, activating dynamic Regional Economic Communities and acting co-operatively at the continental level (AU, 2022).

The African Union is keen to accelerate industrialisation, as can be seen from the discussions at the Summit held in Niamey in November 2022 on the theme, “Industrialisation and economic diversification”. At this summit, specific areas of intervention were identified and discussed.

Technological innovation is usually defined as “the technical, industrial and commercial steps which lead to the successful marketing of new manufactured products and/or to the commercial use of technically new processes or equipment”. Whether innovations stem from a country’s technological capacity or from imitation, they play an important role in the industrialisation process of economies. The pursuit of industrialisation, innovation and development in Africa is not only a response to economic imperatives but also rooted in a broader vision of fostering self-reliance, improving living standards and seising the opportunities of a globalised world. Africa is moving rapidly towards an integrated economic space (AfDB: The Africa Industrialisation Index, 2022).

This introduction sets the stage for a deeper exploration of the multifaceted aspects of industrialisation, technological innovation and development in Africa. From burgeoning tech hubs to ambitious regional strategies and partnerships, this topic is a dynamic and evolving narrative, with the potential to reshape the continent’s future. The following discussion will delve into the various dimensions of this exciting journey, exploring the initiatives, trends and challenges that characterise the push for industrialisation, innovation and development in Africa.

Economic and Social Aspects of Industrialisation

Improving the productivity of existing production units is another aspect of industrialisation. This aspect of industrialisation can happen in the following ways:

- Transforming raw materials is a key aspect of industrialisation, utilising machines and processes to change raw materials into finished or semi-finished products. This includes industries such as iron and steel, chemicals, textiles and food
- Large-scale production, which is often made possible by the mechanisation of processes, leads to a reduction in unit costs and increases productivity
- Development of infrastructure, such as transport, communication and energy networks, facilitates the flow of raw materials, finished products and workers
- Urbanisation results from job creation in industries which attract rural populations to cities. It poses new challenges in terms of housing, sanitation and access to social services
- Social challenges bring about a profound social transformation, affecting family structures, labour relations, cultural values and can also have significant environmental impacts

Role of Innovation in Industrialisation

The role of innovation as a driver of long-term growth, competitiveness and better quality of life has gained acceptance among policymakers. In a developed economy, innovation is seen from the enterprise perspective as a way of increasing sales from the production of new products, goods and services and of developing new industries. In a developing economy, it may be seen as a survival strategy. The literature suggests a positive relationship between innovation and firm performance and growth in the services and manufacturing sectors, which may lead to increased competitiveness. Further, innovative firms are likely to be more export-oriented than their non-innovative counterparts (Pierre Mohnen, 2003). Globally, the importance attached to innovation is articulated in, for example, the innovation Strategy of the OECD and the focus of the European Commission on Innovation (OCDE, 2012).

One of the many ways by which innovation can act on the economic system is by generating new knowledge through research activities and the application of this knowledge in production. Such applications often lead to new products and processes, collectively known as technological innovation. These innovations enhance a country's competitiveness, creating jobs and wealth.

Industrialisation in Africa: Challenges and Opportunities

Africa's journey towards industrialisation is marked by many challenges and opportunities. The challenges which hinder the process of industrialisation include the following: poor governance records, shortage of skilled labour, limited access to financing, inadequate infrastructure and poor or limited sources of energy. There are several issues, including underdevelopment of the middle class, high crime rates, corruption and significant levels of debt. However, Africa is not merely defined by its challenges; it is also defined by several opportunities, such as its resilience, creativity, endowment of natural resources and young people in the population structure who are eager to embrace the digital age and capitalise on emerging technologies. Other opportunities are high rates of urbanisation, a growing labour force and its level of qualification, a growing domestic market, an increasing share of the middle class, a decrease in the severity of internal political confrontation and attenuation of inter-country armed conflict.

2.2 INNOVATION AND INDUSTRIALISATION TRENDS AND DRIVERS IN AFRICA

Globalisation has affected all spheres of Africa's development and opened new commercial opportunities for Africa. According to United Nations projections, Africa will experience unprecedented demographic growth and is expected to account for almost 40% of the world's population by 2100 (as much as China and India combined), compared with almost 17% (2023). Innovation and industrialisation in Africa are subject to various trends and drivers that are shaping the continent's economic landscape. Understanding these dynamics is crucial for both policymakers and investors. Here is an overview of the key drivers and trends of innovation and industrialisation in Africa:

Focusing on the drivers of innovation and industrialisation in Africa, Christ-Arsène Ouinsou (2021) identifies that innovation impacts industrialisation through two primary channels: boosting the productivity of existing production units and developing new activities. What are the drivers of industrialisation through innovation to develop Africa?

Foreign Direct Investment (FDI) and Political Reforms

The recent continental, regional and national policy initiatives are driven by the recognition that industrialisation and innovation through domestic and foreign investments are the engines of economic transformation and sustainable development (John Ouma-Mugabe, 2020). According to the (AfDB: The Africa Industrialisation Index, 2022), the combination of private sector growth and the increase of total FDI enables countries to raise their industrialisation capabilities and what makes that happen is the political stability. There is a need for commitment by Member States on the implementation of policy and economic reforms that should be homegrown to promote industrialisation on the continent.

Education, Training, Entrepreneurship, Financial Inclusion and International Partnerships

Investing in education and technical training is essential to develop the skilled workforce needed for innovation and industrialisation. Encouraging entrepreneurship and initiatives to support small and medium-sized enterprises (SMEs) on the continent has increased the development of start-ups that play a key role in promoting innovation through job creation. Globally, many improvements are observable in financial systems alongside technological advancements and greater innovation (Shen Yap, 2023). However, despite these developments, as many as 1.7-billion people are still excluded from formal financial systems (World Bank, 2017). Therefore, extending access to financial services will enable more people to be included in the formal economy and certainly stimulate economic innovation. it is crucial to establish a broad, country-specific process that leverages financial and non-financial resources, promotes regional integration and mobilises cooperation between Africa's development partners. Cooperation with international partners, including international organisations, NGOs and foreign governments, can stimulate innovation and industrialisation by promoting the transfer of knowledge and technology.

2.3 TRENDS OF INNOVATION AND INDUSTRIALISATION IN AFRICA

Technology and Digital Transformation

Ndubuisi (2023) analyses Technological Capabilities and Industrialisation in Africa. The author sampled 50 African countries between 2000 and 2018, finding strong heterogeneities in the levels of technological capabilities among countries on the continent. The study shows that "the average technological capability in African states has almost doubled, increasing from 25% to 41% which is linked to increasing internet penetration and rapid diffusion of digital technologies across the countries". The rapid adoption of mobile technologies has paved the way for innovative services. Africa has been experiencing a digital transformation, with the adoption of digital technologies in various sectors, including finance, healthcare, education and e-commerce. Fintech, e-commerce and digital payment solutions have gained momentum, driving innovation and economic growth. Gaglio et al (2022) provide insights into the steady but uneven pace of digitalisation in African manufacturing, highlighting the structural and contextual factors shaping this trajectory. The authors underscore that while digital technologies are increasingly present in sectors like textiles, food processing and automotive manufacturing, their adoption remains constrained by limited infrastructure, inadequate digital skills and weak linkages between industry and research institutions.

African countries have seen a surge in tech startups, particularly in major urban centres. These startups are contributing to innovation in various fields, including agriculture, health and education. Tech hubs and incubators have proliferated, fostering entrepreneurship and innovation. Innovation in agriculture, agro-industry and the food supply chain is becoming increasingly important to improve food security and stimulate economic growth. By harnessing digital innovation, it can foster inclusive and resilient agricultural systems that enhance the livelihoods of rural communities while safeguarding the planet's resources. Agriculture remains a cornerstone of many African economies. The adoption of innovation around genomics[1], such as genetically modified organism Genome Editing[2] to improve agricultural productivity is on the rise on the continent. Innovations in agribusiness, such as precision farming, agritech and improved crop management techniques, are transforming the sector and driving industrialisation.

Mobile Technology, e-Government Initiatives, 3D Printing, Artificial Intelligence (AI) and Local Manufacturing

The adoption of 3D printing technology is growing in Africa. This technology allows for localised manufacturing, reducing the need for imports and promoting industrial growth. Africa has a rapidly expanding mobile phone market. Mobile technology is not only driving communication but also fostering mobile banking, health services and education, contributing to innovation and economic development. Governments across Africa are implementing e-government services to improve efficiency, reduce bureaucracy and enhance transparency. This has the potential to stimulate innovation in the public sector and related industries.

1 GMOs in Africa: Status, adoption and public acceptance – ScienceDirect
2 Policy Framework for Applications of Genome Editing.pdf (au-apet.org)

AI in Africa offers transformative opportunities for industrialisation, but it also raises concerns about job displacement, particularly in labour-intensive sectors. This challenge has prompted governments organisations and businesses to adopt a dual approach: fostering AI development while safeguarding human employment through reskilling, education and AI governance policies. The African Union underscores AI's pivotal role in achieving Agenda 2063 and global sustainability objectives, emphasising its potential to ignite new industries and advance integration across the continent. At the national level, countries are making efforts to align these opportunities with the necessary efforts in skills development. For example, South Africa has committed to training one million individuals in AI and cybersecurity skills by 2026, aiming to enhance its technological capabilities and competitiveness (Dludlam, 2025)[3].

African Continental Free Trade Area (AfCFTA), Circular Economy Initiatives and Tourism Innovation

The implementation of AfCFTA has the potential to stimulate industrialisation and innovation by creating a single market for goods and services across the continent. It is expected to boost intra-African trade and encourage the development of regional value chains. Some African countries are embracing the circular economy concept, which promotes recycling, resource efficiency and sustainable practices. This trend is driving innovation in waste management and green technologies through the reduction of single-use plastics, the use of biodegradable materials and the promotion of reusable and recyclable products.

Tourism is a significant industry in Africa and innovative approaches to eco-tourism, cultural tourism and digital tourism experiences are on the rise. Digital technology is transforming the tourism industry in Africa. This includes mobile apps for booking accommodations and activities, online travel guides and virtual reality experiences that allow travellers to explore destinations from afar.

Renewable Energy, Space and Satellite Technology

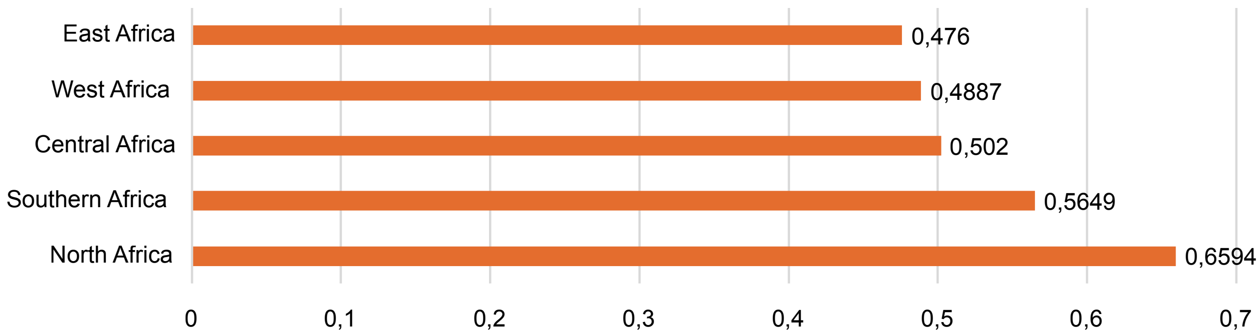
The continent is increasingly investing in renewable energy sources, particularly solar and wind power, to address energy-related challenges and promote sustainable industrialisation. Today, many rural and remote areas, as well as cities in Africa, are benefiting from innovations like off-grid solar solutions that provide clean energy. Furthermore, African nations are making investments in space exploration and satellite technology, which have important applications in agriculture, environmental monitoring and disaster management.

2.4 STATUS OF THE MANUFACTURING INDUSTRY AND INFRASTRUCTURE IN AFRICA

Industrialisation in Africa is a complex subject that varies considerably from one country to another due to economic, political and geographical differences. Industrial development is the key to Africa's prosperity. Some African economies have made significant progress in industrialisation and have developed relatively diversified manufacturing sectors. According to a report published in 2022 by the African Development Bank (AfDB), in collaboration with the African Union (AU) and the United Nations Industrial Development Organisation (UNIDO), 37 out of the 55 AU Member States, excluding Somalia and South Sudan (for which there is no data), experienced an increase in their level of industrialisation from 2010 to 2021.The regional analysis shows that North Africa (average score: 0.6594) is the most advanced region for industrial development in Africa, followed by Southern Africa (0.5649), Central Africa (0.5020), West Africa (0.4887) and East Africa (0.47602). The ranking of these five regions remained unchanged over the 2010-2021 period.

3 https://www.reuters.com/technology/artificial-intelligence/microsoft-train-1-million-south-africans-ai-skills-2025-01-23/

Figure 2.1 Industrialisation average score in Africa



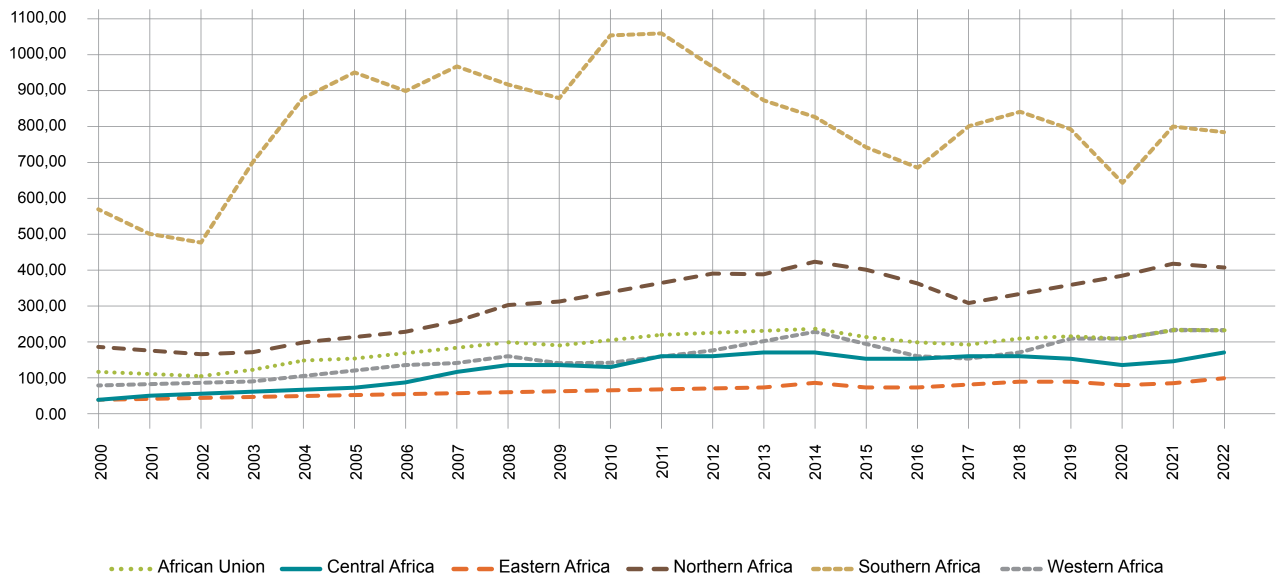
Source: AII, 2022

UNIDO defines industrial competitiveness as the capacity of countries to increase their presence in international and domestic markets whilst developing industrial sectors and activities with higher value-added and technological content. Meaning that, it is impossible to imagine industrial development without exposing the local manufacturing sector to international competition. While the gross value added is the key factor in the production approach, calculated for each industry and serving as an indicator of the economic performance of each industry, the manufacturing value added (MVA) is a well-recognised and widely used indicator by researchers and policymakers to assess the level of industrialisation of a country. The share of MVA in GDP reflects the role of manufacturing in the economy and a country's national development in general. MVA per capita is the basic indicator of a country's level of industrialisation adjusted for the size of the economy.

The gross value-added measures the contribution to the economy of each producer, industry or sector in a country. The gross value added generated by any unit engaged in production activity can be calculated as the residual of the units' total output less intermediate consumption, goods and services used up in the process of producing the output or as the sum of the factor incomes generated by the production process (UNIDO, 2008). Manufacturing refers to industries belonging to the sector C defined by the International Standard Industrial Classification of All Economic Activities, Revision 4 (ISIC Rev.4) or to the sector D defined by the International Standard Industrial Classification of All Economic Activities, Revision 3.1 (ISIC Rev.3.1). One of the statistical uses of MVA per capita is classifying country groups according to the stage of industrial development. Thus, MVA measures an exclusive and exhaustive contribution of manufacturing to GDP (Andreoni A, 2014).

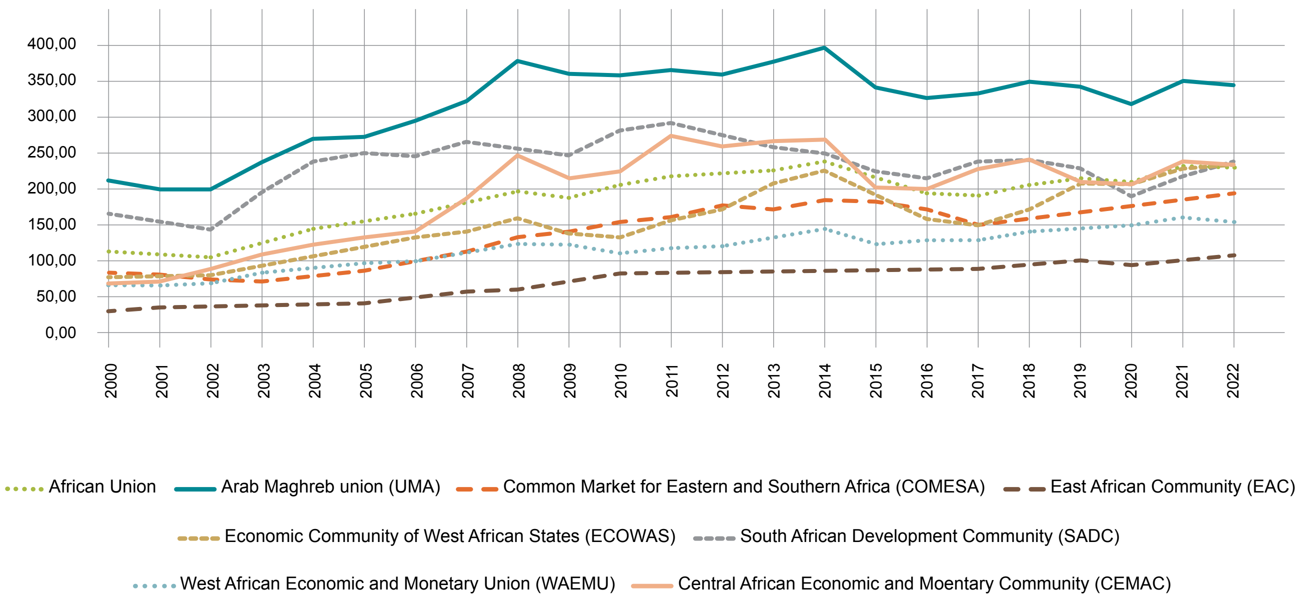
The disparity in industrial development between the southern region and other regions of the African continent is significant, with the northern region following closely behind. This gap can be attributed to the presence of South Africa, the continent's leading economic power, in the southern region, as well as Morocco and Egypt in the northern region. In contrast, the eastern region, which includes Somalia, Sudan, South Sudan, Uganda, Burundi and Tanzania, is the least industrialised area on the continent.

Figure 2.2 Manufacturing value added per capita, constant 2015 USD per capita in the Africa regions.



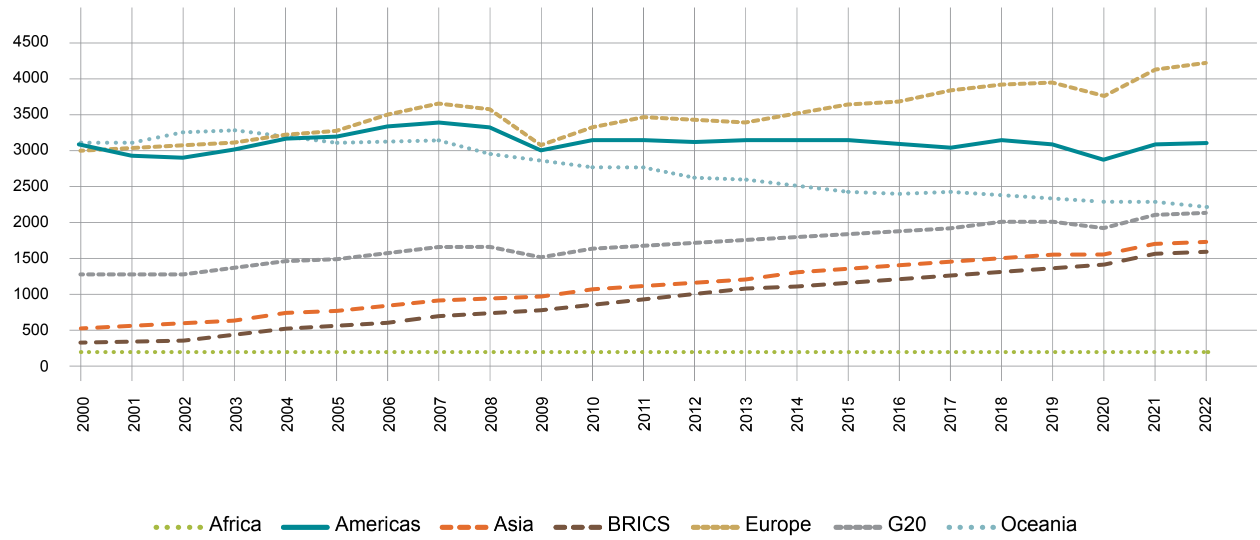
The regional community analysis in Africa highlights the Arab Maghreb Union (AMU) and the Southern African Development Community (SADC), along with the Central African Economic and Monetary Community (CEMAC). Within CEMAC, we find countries such as Gabon, Congo-Brazzaville and Equatorial Guinea. This analysis shows the East African Community again as the least industrialised community region.

Figure 2.3 Manufacturing value added per capita, constant 2015 USD per capita in the RECs.



When comparing Africa to other continents regarding industrial development, it becomes clear that Africa is the least industrialised continent in the world, trailing behind Asia. This situation may stem from the various challenges faced by business owners in the sector. For instance, Africa's manufacturing industry has been criticised for its low level of value addition, where raw materials are exported in their unprocessed form and manufacturing is limited to basic assembly. In addition, African manufacturers often face competition from global industries that benefit from economies of scale and advanced technologies. Local manufacturers often face challenges when it comes to competing on both cost and quality. Moreover, many SMEs in the manufacturing sector struggle to access affordable financing. The limited access to capital in most African countries also hampers the growth of these businesses. Political stability, corruption and the quality of governance play a key role in the industrialisation process. These challenges contributed to the slight increase in manufactured value added per capita observed in African businesses between 2000 and 2022.

Figure 2.4 Manufacturing value added per capita, constant 2015 USD per capita in the World



Source: UNIDO, 2023

2.5 MINISTERIAL DECISIONS ON STI AND INDUSTRIALISATION SINCE 2003

Science and Technology (S&T) and Innovation are recognised as enablers of socio-economic transformation in the current knowledge-based and innovation-led economy. Taken briefly as a continent, Africa is willing to change its narrative of having 33 Member States in the African Union classified as least developed countries (LDCs), with 73% of the 45 countries worldwide found in the same category. The second ten-year implementation plan (STYIP) of Agenda 2063 aims to take AU Member States from low to middle-income level countries. In the AU action plan for accelerated industrial development of Africa, two requirements aligned with indicators have been flagged linking research to industrialisation: (i) an increased investment in research from all 4 traditional performing players (business, government, higher education and non-profit organisation) with an overall minimum of 1% of gross domestic expenditure (GDP) known as *gross domestic expenditure on R&D* (GERD); and (ii) a least 5% investment in research from the total general government budget.

Research and innovation constitute a set of strong boosters in all the economic sectors and can influence the expected change by 2030 to achieve the SDGs but also by 2033 and 2034 to achieve both the 8 aspirations/moonshots of the second Ten-year implementation plan of Agenda 2063 (STYIP) and the strategic priorities of STISA-2034 respectively. In combining Industrialisation, infrastructure and innovation in which both intramural/extramural research are embedded, the 2030 Agenda has purposely linked STI and Industrialisation to connect the dots between STI indicators and industrialisation.

AIO-2024 has prioritised highlighting the connection between STI and industrialisation in flagging a series of decisions taken at the AU levels.

To achieve the targets set by Agenda 2063 (Goal 2, Priority Area 2) and the 2030 Agenda (UN Sustainable Development Goal 9) for transforming Africa through Science, Technology and Innovation (STI), the following measures are essential:

First, GERD as a percentage of GDP should reach at least 1% by 2023. Second, under the Accelerated Industrial Development for Africa (AIDA), national governments are required to allocate at least 5% of their budgets to research, in addition to the 1% GERD mentioned above.

Emphasising how AU decisions contribute to the achievement of research and development (R&D) targets can significantly impact economic growth in various countries. It is important to identify which sectors yield the best value for money in terms of public financing for R&D. African nations should monitor government contributions to R&D expenditures as a percentage of GDP before evaluating the performance of businesses, higher education institutions and private non-profit organisations.

Decisions supporting industrialisation, research and innovation were tracked from 2003, cognisant of the initial pledge from the Lagos Plan of Action of the then Organisation of African Unity (OAU) for socio-economic transformation, focusing on 1% of GDP for scientific capabilities.

Table 2.1 African Union decisions & declarations of the Assembly on Industrialisation, Science, Technology and Innovation

Date	Venue	When	Title	Reference
17-18 Feb 2024	Addis Ababa, Ethiopia	37th Ordinary Session of the Assembly of the Union	Decision on The Report of the African Union Development Agency (AUDA-NEPAD) Heads Of State and Government Orientation Committee	Assembly/AU/ Dec.875(XXXVII)
05-06 Dec. 2022	Addis Ababa, Ethiopia	36th Ordinary Session of the Assembly of the Union	Ministerial Declaration of Algiers on Start-Ups in Africa	Assembly/AU/Decl 1(XXXVI)
9-10 Feb. 2020	Addis Ababa, Ethiopia	33rd Ordinary Session of the Assembly of the Union	Decision of the Report of the Committee of Ten Heads of State and Government Championing Education, Science and Technology	Assembly/AU/Dec.790(XXXIII)
28- 29 Jan. 2018	Addis Ababa, Ethiopia	30th Ordinary Session of the Assembly	Decision on the New Partnership for Africa's Development (NEPAD) Doc. Assembly/AU/12(XXX)	Assembly/AU/Dec.685(XXX)
28- 29 Jan. 2018	Addis Ababa, Ethiopia	30th Ordinary Session of the Assembly	Decision on the Inaugural Meeting of the Committee of Ten Heads of State and Government as African Champions of Education, Science And Technology Doc. Assembly/Au/11(XXX)	Assembly/AU/Dec.671(XXX)
17-18 July 2016	Kigali, Rwanda	27th Ordinary Session of the Assembly of the Union	Decision On the New Partnership for Africa's Development (NEPAD) Doc. Assembly/Au/7(Xxvii)	Assembly/AU/Dec.618 (XXVII)
30-31 Jan 2016	Addis Ababa, Ethiopia	26th Ordinary Session of the Assembly of the Union	On The Specialised Technical Committee on Education, Science and Technology (Stc-Est 1)-Doc. Ex.Cl/934(Xxviii)	Assembly/AU/Dec.589(XXVI)
14-15 June 2015	Johannesburg, South Africa	25th Ordinary Session of the Assembly of the Union	On The Outcomes of the Dakar Summit on Higher Education – Doc. Assembly/Au/17(Xxv)Add.2	Assembly/AU/Dec.572(XXV)
30-31 Jan 2015	Addis Ababa, Ethiopia	24th Ordinary Session of the Assembly of the Union|	Decision On the Report of Heads of State on the Government Orientation Committee (HSGOC) On NEPAD Doc. Assembly/Au/10(Xxiv)	Assembly/AU/Dec.563(XXIV)
26-27 June 2014	Malabo, Equatorial Guinea	23rd Ordinary Session of the Assembly of the Union|	Decision on Strategy for Science, Technology and Innovation in Africa 2024 – Doc. EX.CL/839(XXV)	Assembly/AU/Dec.520(XXIII)
26-27 June 2014	Malabo, Equat. Guinea	23rd Ordinary Session of the Assembly of the Union	Decision on African Observatory for Science, Technology and Innovation (AOSTI) – Doc. EX.CL/839(XXV)	Assembly/AU/Dec.521(XXIII)
26-27 June 2014	Malabo, Equat. Guinea	23rd Ordinary Session of the Assembly of the Union	Decision On Pan African Intellectual Property Organisation (PAIPO) Doc. EX.CL/839(XXV)	Assembly/AU/Dec.522(XXIII)
26-27 June 2014	Malabo, Equat. Guinea	23rd Ordinary Session of the Assembly of the Union	Decision On African Scientific Research and Innovation Council (ASRIC) Doc. Ex.Cl/839(XXV)	Assembly/AU/Dec.523(XXIII)

Date	Venue	When	Title	Reference
26-27 June 2014	Malabo, Equat. Guinea	23rd Ordinary Session of the Assembly of the Union	Decision On the International Salon on Invention and Innovation Doc. Ex.Cl/839(XXV)	Assembly/AU/ /Dec.524(XXIII)
26 May 2013	Addis Ababa, Ethiopia	21st Ordinary session of the Assembly of Heads of State and Government of the African Union	Decision on the agenda for social and economic development	Assembly/AU/Decl 3(XXI)
27-28 Jan. 2013	Addis Ababa, Ethiopia	20th Ordinary Session of the Assembly of the African Union	Decision on the Creation of the African Observatory on Science, Technology and Innovation in the Republic of Equatorial Guinea – Doc. EX.CL/766(XX)	Assembly/AU/Dec.452(XX)
28-28 Jan 2013	Addis Ababa, Ethiopia	20th Ordinary Session of the Assembly of the African Union	Decision on the Creation of the African Observatory on Science, Technology and Innovation in the Republic of Equatorial Guinea – Doc. EX.CL/766(XX)	Assembly/AU/Dec.452(XX)
25-27 July 2010	Kampala, Uganda	15th Ordinary Session of the Assembly of the African Union	Decision on the Third African Conference on The Application of Space Sciences and Technologies for Sustainable Development in Africa Doc. Assembly/AU/17(XVII) Add.6	Assembly/AU/Dec.325(XV)
26-27 July 2010	Kampala, Uganda	15th Ordinary Session of the Assembly of the African Union	Decision To Support the Square Kilometre Array (SKA) Project on the African Continent Doc. EX.CL/584(XVII)	Assembly/AU/Dec.303(XV)
27-27 July 2010	Kampala, Uganda	15th Ordinary Session of the Assembly of the AU	Decision On the Third African Conference on The Application of Space Sciences and Technologies for Sustainable Development in Africa Doc. Assembly/AU/17(XVII) Add.6	Assembly/AU/Dec.325 (XV)
31 Jan-2 Feb 2010	Addis Ababa, Ethiopia	14th Ordinary Session of the Assembly of the AU	Addis Ababa Declaration on Information and Communication Technologies in Africa: Challenges and Prospects for Development Doc. Assembly/AU/11(XIV)	Assembly/AU/Decl 1(XIV)
1-3 February 2009	Addis Ababa, Ethiopia	12th Ordinary Session of the Assembly of the AU	Decision on the Proposal by the Government of the Republic of Equatorial Guinea to host the African Observatory of Science, Technology and Innovation – Doc. Assembly/AU/8(XII) Add.5	Assembly/AU/Dec.235(XII)
30June-1July 2008	Sharm El-Sheikh, Egypt	11th Ordinary Session of the Assembly of the AU	Declaration On Responding to the Challenges of High Food Prices And Agriculture Development	Assembly/AU/Decl 2(XI)

Date	Venue	When	Title	Reference
31Jan-2 Feb 2008	Addis Ababa, Ethiopia	10th Ordinary Session of the Assembly of the AU	Decision on the Implementation of Science and Technology Consolidated Plan of Action – Doc. EX.CL/385 (XII)	Assembly/AU/Dec.172 (X)
32 Jan-2 Feb 2008	Addis Ababa, Ethiopia	10th Ordinary Session of the Assembly of the AU	Decision on the Establishment of an African Education, Science and Technology Fund	Assembly/AU/Dec.174 (X)
29-30 Jan. 2007	Addis Ababa, Ethiopia	8th Ordinary Session of the Assembly of the AU	Decision on the Report of the Extraordinary Conference of Ministers of Science and Technology – Doc. EX.CL/315 (x)	Assembly/AU/Dec.161 (VIII)
29-30 Jan 2007	Addis Ababa, Ethiopia	8th Ordinary Session of the Assembly of the AU	Addis Ababa Declaration on Science, Technology and Scientific Research for Development	Assembly/AU/Decl 5 (VIII)
4-5 July 2005	Sirte, Libya	5th Ordinary Session of the Assembly of the AU	Declaration On the Review of The Millennium Declaration and The Millennium Development Goals (MDGs)	Assembly/AU/Decl. 1 (V)
6-8 July 2004	Addis Ababa, Ethiopia	3rd Ordinary Session of the Assembly of the AU	Decision On the Implementation of the New Partnership for Africa's Development (NEPAD)	Assembly/AU/Dec.38 (III) Rev.1
10-12 July 2003	Maputo, Mozambique	2nd Ordinary Session of the Assembly of the AU	Declaration On the Implementation of The New Partnership for Africa's Development (NEPAD)	Assembly/AU/Decl 8 (II)

Source: African Union Common repository | https://archives.au.int/

2.7 RECOMMENDATIONS AND CONCLUSIONS

Improving industrialisation is a critical issue for the structural transformation of all economies, in Africa and elsewhere. While the southern and north African countries are very industrialised, it has been observed that the contribution of the industrial sector, particularly the manufacturing sector, to the GDP in terms of value-added, of African countries compared to the rest of the World, is very low. This means that innovation is lacking in the industrial sector and we need to look at ways of improving industrial development in African countries. Industrialisation, technological innovation and development are still ongoing processes. Although progress has been made in some countries, more remains to be done to promote sustainable, diversified and inclusive industrialisation, technological innovation and development on the continent. To manage the process of industrialisation, African Heads of State need to encourage the development of new technologies by funding research activities and facilitating the use of foreign technologies, working towards the development of infrastructure, improvement of investment climate, transparency of legislation, reduction of administrative costs for business, reduction of corruption, prevention of armed conflicts.

Countries that have succeeded in advancing industrialisation have generally implemented economic reforms, improved their business climate, invested in education and training, encouraged technological innovation and established partnerships with the private sector. Africa is experiencing a significant transformation in innovation and industrialisation. While challenges persist, such as infrastructure gaps and regulatory hurdles, the continent is harnessing its youthful population, digital technologies and renewable energy sources to drive economic growth and improve the quality of life for its people. Collaboration, investment and forward-thinking policies are essential drivers in this exciting journey towards a more prosperous and innovative Africa.

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CHAPTER 3
AFRICA'S STI LANDSCAPE FOR ACCELERATED INDUSTRIALISATION

3.1 ECONOMIC AND HUMAN DEVELOPMENT CHALLENGES FOR STI IN AFRICA

3.1.1 Background

There are several, often contradictory but strongly interlinked, aspects to the debates on the relationship between human development and that of STI. These include the version of the national system of innovation as the framework of STI policy, which is adopted. Rather than the usually considered binary choice between narrow and broad versions, we should think of a range of breadth, mainly based on:

i The notions of innovation, primarily technological and non-technological and the complex relationships between these two categories; non-technological innovations cover a wide range of institutional changes, from organisational change in the firm, social relations and governance systems

ii The type and variety of institutions deemed relevant depend largely on how innovation is conceptualised. While formal institutions are often the focus, informal institutions that play a crucial role in the formation of tacit knowledge are frequently overlooked

The understanding of the human role in the economy is crucial. A key distinction exists between human capital theory and the human capabilities approach.

i Human capital theory (see Becker, 1962) sees education as the base of human development and primarily as a private good driven by expected lifetime returns on investment in education

ii Human capabilities, on the other hand, look at the development of the human from a holistic perspective, which covers all basic needs in conjunction. The development of human capabilities is seen as the freedom of individuals to achieve their lifetime potential and development as the freedom from any constraints on attaining this objective (Sen, 1999)

iii The distinction between the two approaches is critical to understanding of the role of humans in the development of national systems of innovation, depending on the context. Africa has been consistently marked by extremely low enrolment rates in higher education over time, compared to the rest of the world (see Figure 3.1) and it is likely that the wrong approach towards investing in human development may be a significant determinant of this shortfall. Simultaneously, the low absorptive capacity for skills in most African countries has consistently contributed to an ongoing depletion of skills through the emigration of skills out of Africa (Scerri, 2020)

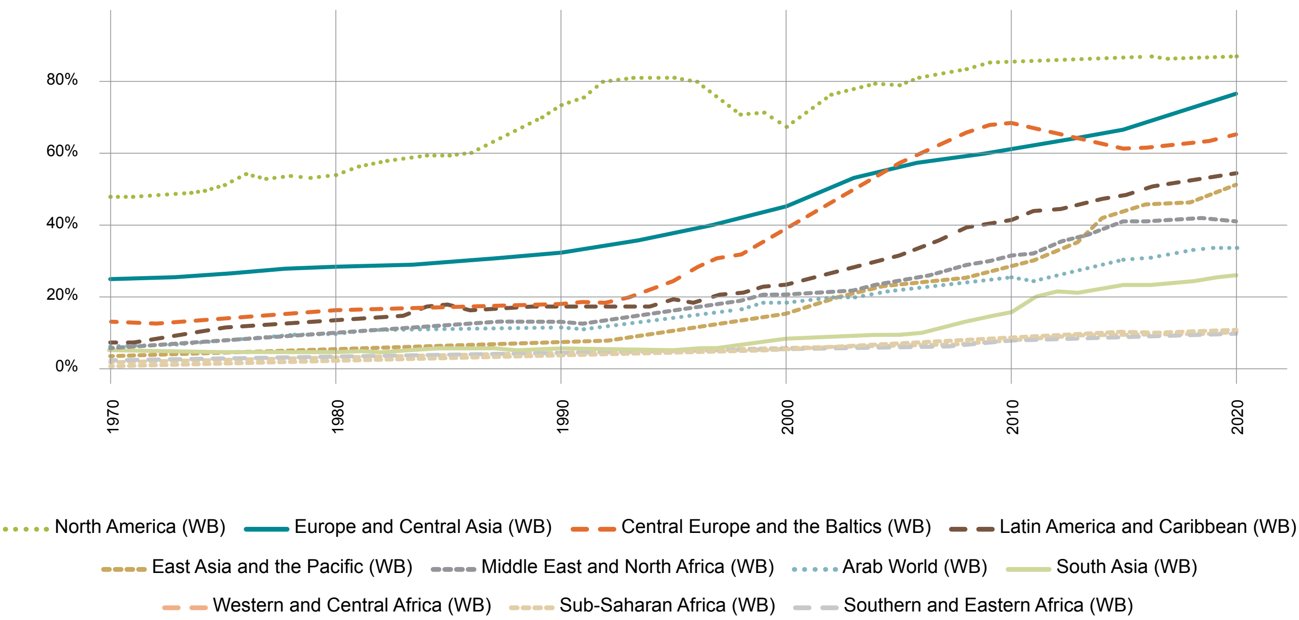
The economic setting for the understanding of the role of human development in STI development and the consequent policy implications, with the following implications:

i In the case of developed economies, we can normally assume that most of the provisions underlying a sound and thriving human capabilities base can be assumed as given. This is not necessarily uniform across the wide range of developed economies, where the Anglo-American largely neoliberal policy framework still places a substantial burden of basic needs provision on individuals. It is also true that in the case of successfully developing economies, the state has taken on a significant role in providing welfare safety nets, guaranteeing sustainable safety nets within which human capabilities development is assured.

ii In the case of African economies, it is often the case that there is a substantial and enduring shortfall in the sustained delivery of the range of basic services required for the inter-generational build-up of the human capabilities base required for the development of an STI drive necessary for economic development.

iii Human capabilities development requires the removal of a wide range of exclusionary mechanisms, based on class, gender, sexual orientation and ethnicity, among other categories, to enable the freedom to achieve individual potential. In many cases, this lack of freedom is strongly associated with non-participatory governance systems, cultural inhibitors and national economic dependency patterns.

Figure 3.1 Gross enrolment ratio in tertiary education, 1970 to 2020



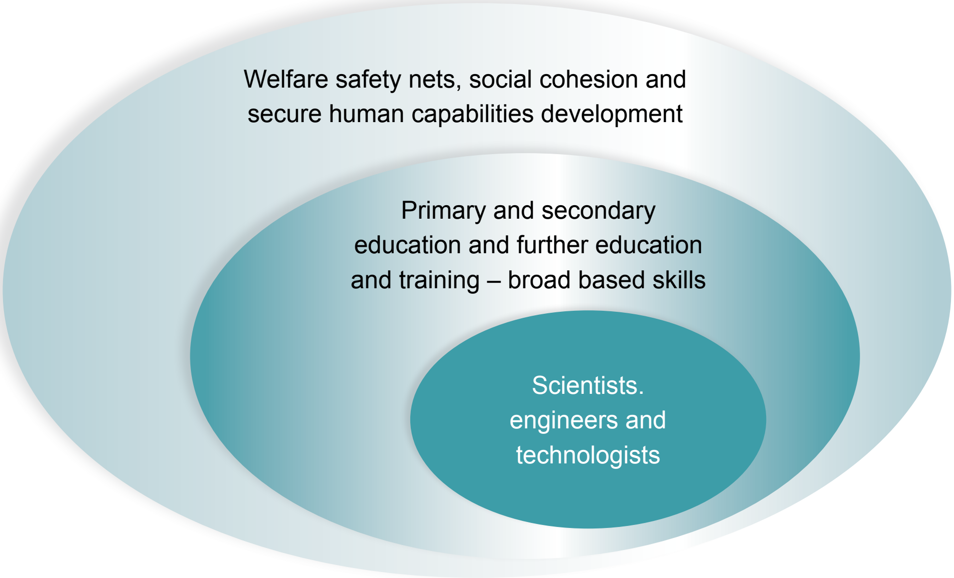
Source UNESCO data from OurWorldInData [https://ourworldindata.org/grapher/gross-enrollment-ratio-in-tertiary-education]

Gross enrolment ratio in tertiary education: The percentage of individuals in any age group who are enrolled in tertiary education is calculated based on the total population of the corresponding five-year age group that follows secondary school graduation. Tertiary education, according to the International Standard Classification of Education (ISCED) levels 5, 6, to 8, builds upon secondary education by providing specialised learning opportunities in various fields. It targets advanced levels of complexity and specialisation, encompassing both academic and advanced or professional education.

3.1.2 Implications for the Relationship Between Human Development and STI

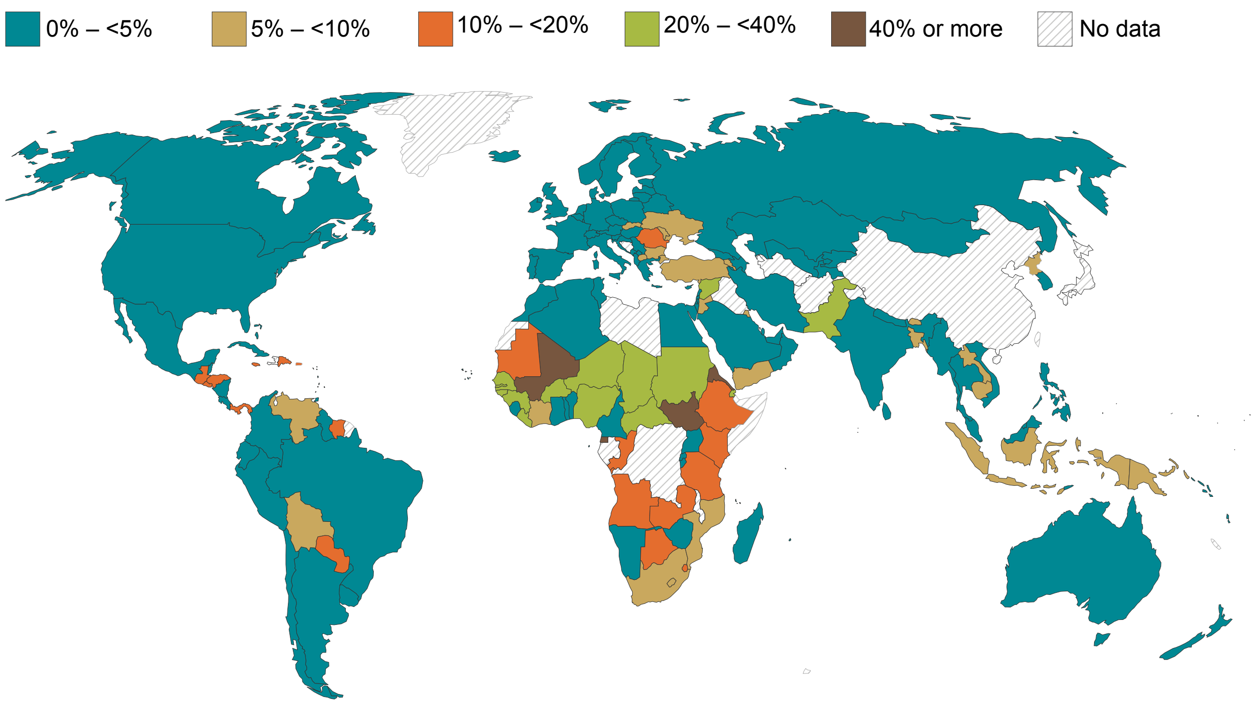
The understanding of STI from a narrow perspective on the national systems of innovation and the design of relevant policy generally considers higher-end skills levels, namely scientists, engineers and technologists, as the relevant human development category. In this case, the data depicted in Figure 1 should be particularly worrying. From the narrow perspective on the system of innovation, STI policy resolutions would focus on increasing access, mostly through increased funding (while probably not changing the funding models) and increasing capacity, probably focusing on enlarging and enhancing the teaching body. However, the fifty-year enduring shortfalls depicted in Figure 1 should indicate that it is not so much 'more of the same' that is needed, as a fundamental rethinking of the determinants of the quality of the human element in the system of innovation. From a broader perspective on the NSI, the poor enrolment rates would be seen as symptomatic of a broader and much more fundamental obstacle to the development of the national system of innovation and the economy. From this perspective, we would be required to shift our understanding of the role of the human in the national system of innovation from one based on human capital theory to the human capabilities approach. In this context, the topographical representation of the foundational levels of human capability development, illustrated in Figure 3.2, is important for understanding the ongoing shortfall in the provision of Science, Engineering and Technology (SET) education. At the most fundamental level, it is evident that the performance of primary and secondary education, which serves as the immediate feeder into higher education, is lacking in Africa. This is highlighted by the primary out-of-school rates shown in Figure 3.3.

Figure 3.2 The layers of human capabilities formation



Source: IERI (2014)

Figure 3.3 Primary out-of-school rate, 2018 or latest year

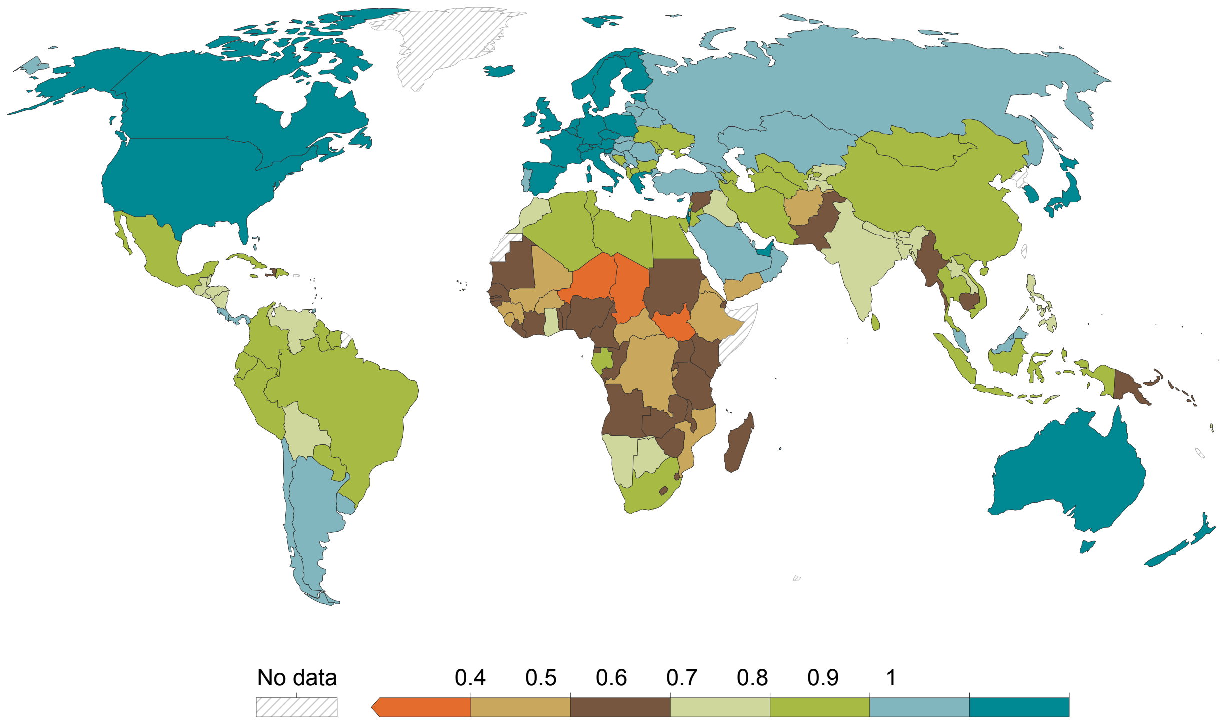


Source: UNESCO (2019) New Methodology Shows that 258 Million Children, Adolescents and Youth Are Out of School. Fact Sheet no. 56, UIS/2019/ED/FS/56, at https://uis.unesco.org/sites/default/files/documents/new-methodology-shows-258-million-children-adolescents-and-youth-are-out-school.pdf

Note: The depiction and use of boundaries and related data shown on this map are not guaranteed to be error-free, nor do they necessarily imply official endorsement or acceptance by UNESCO.

One further consideration should be that the role of humans in the system of innovation should be extended to the whole of the labour force, not just scientists, engineers and technologists and to the population as the generative base for human capabilities. Sound national systems of innovation are based on an innovative and enterprising labour force at every layer. This determines both the absorptive capacity for technology, as well as an important ground-level source of innovation. In this sense, we need to consider the embeddedness of the human capabilities in the material and social conditions of the lives of the population. In the absence of this consideration, any attempts to solve the 'human capital problem' at the apex of the skills pyramid can only have minor and short-term results. Without an examination of the structural impediments to the development of broad-based technological capabilities (Lall, 1992), the disjunction between human development and the evolution of the national system of innovation will be a permanent feature of systems of innovation in Africa. An approximation to the assessment of these impediments to human development at the base level in Figure 3.3 may be found in the Human Development Index as depicted in Figure 3.4, which shows that most African economies show a low human development index relative to most other parts of the world.

Figure 3.4 Human Development Index, 2022



Data source: UNDP, Human Development Report (2024) – https://ourworldindata.org/grapher/human-development-index?time=latest

Note: The Human Development Index (HDI) is a summary measure of key dimensions of human development: a long and healthy life, a good education and a decent standard of living.

Higher values indicate higher human development.

3.1.3 Policy Implications

Three key STI policy directions emerge from the numerous factors affecting the relationship between human development and STI.

- It should be clear that the state must play a central role in overcoming obstacles to development, whether this is understood as economic growth, advancing the national system of innovation or focusing specifically on the narrow Science, Technology and Innovation (STI) sector. If the state does not assume this responsibility, a vicious cycle will persist, characterised by low capability levels that hinder economic development and limit the ability to absorb skills. This, in turn, leads to a drain of human talent, further restricting the progress of the national system of innovation. This is what maintains the low human capabilities trap that is evident all over the continent. Arguably, the heavy constraint that this trap imposes on economic development and the evolutionary prospects of systems of innovation in Africa has not significantly abated since the emergence of post-colonial Africa
- Effective STI policies will have to extend considerably beyond the traditional STI focus areas if it is to be effective. This is where the transplant of policy frameworks developed in the 'global north', where the structural conditions for the ongoing development of the human capabilities based can be assumed as given and well-functioning, can be so very ineffective in Africa where lessons learnt by the Asian Tigers and other newly industrialising economies on appropriate policy have largely been ignored. This broad approach implies the dismantling of the fragmented policy landscape that characterises most of the economies in the region, the shifting of the responsibility for delivery on a range of basic needs to the state and the effective long-term guarantee of the integrity of the family unit, in all its aspects, as the long-term incubator of human capabilities
- The primary policy shift is moving away from a dependency-led accumulation regime (Scerri, 2021), which is especially prevalent across Africa and may encapsulate the root of many development failures on the continent. It certainly severely limits the local absorptive capacity for human capabilities and thus lays the enduring foundation for the low-level human capabilities trap which still cripples the development of STI

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3.2 COUNTRY GDPs, EXPORT AND IMPORT PROFILES: POTENTIAL FOR INNOVATION AND VALUE ADDITION FOR COMPETITIVE ADVANTAGE STATUS

3.2.1 Background

This section explains the relationships between countries' GDP, their economic structures, levels of technological capabilities and how these factors relate to their levels of development. It starts with a pertinent question on why some countries are rich and others are poor. The growth theory argues that country differences in research and development and human capital lead to differential growth in technical change and accumulation (Aghion and Howitt 1992; Grossman and Helpman 1991). Further, Constantine (2017) argues that differences in economic performance of countries can be explained by: first, the differences in economic and political institutions; and second, the differences in economic structures; and that the important process is structural transformation. These factors call for countries to invest in education and innovation. High value-added and technologically complex goods are produced in market structures that are conducive to innovation

(Nelson and Winter 1990). This scenario sustains higher wages and profits for longer periods (Reinert 2008). According to Constantine (2017) the emerging consensus is that lower inequality is growth-intensive. This observation is supported by Singh (2006), who argues that along with raising productivity and standards of living, institutional organisational and cultural changes make society at large more capable, equal, productive, innovative and peaceful.

This section evaluates the export and import dynamics among countries in Africa, focusing on potential innovation and value addition for achieving competitive advantage. Since African countries are rich in various natural resources, the technologies and capabilities necessary to develop higher-value products will vary from one country to another. The recommendations address the degree to which African countries are transitioning toward more technology-intensive economic sectors, as well as the policies and institutions needed to accelerate this process.

3.2.2 GDPs and the Economic Structures of Countries

In the subsequent section, secondary information and data are used to expose the economic structures of African countries, where statistics could be obtained. Analysing African country GDPs, export and import profiles provides valuable insights into their economic landscapes and potential for innovation. For example, African countries have diverse economies supported by sectors such as oil and gas, mining, manufacturing and agriculture, contributing significantly to their GDP. Understanding the specific export and import profiles of each country may highlight key industries and trading partners, offering opportunities for value addition and competitive advantage. By focusing on strategic sectors and fostering innovation, African countries can leverage their strengths to enhance economic growth and global competitiveness. The total trade volume, which is the sum of imports and exports in USD millions per country, can explain the economic structure and any potential innovation opportunities.

Figure 3.5 overleaf, titled “Total Trade Volume by Country”, provides a visual representation of the total trade volume for the different African countries. The tallest bar indicates **South Africa** has the highest trade volume, suggesting it is a major hub for trade on the continent. **Egypt, Algeria, Nigeria and Angola** also show significant trade volumes, indicating strong economic activities and possibly higher levels of industrialisation or resource exportation. Countries with smaller bars, such as Cape Verde, Burundi, Djibouti, Sierra Leone, Gambia, Central African Republic, Comoros, Chad, Eritrea, Sao Tome and Guinea-Bissau, have lower trade volumes, which might be due to smaller economies, less industrialisation or lower levels of international trade. This implies that economic activity is highly concentrated in a few key countries within the continent and suggests that policymakers identify countries with high trade volumes for potential trade agreements or partnerships for integration. On the other hand, investors may look at countries with high trade volumes as potential markets for investment due to their significant economic activity.

Also, in terms of trade distribution, the chart shows a significant variation in trade volumes across countries. This indicates differing levels of economic activity and trade engagement in different nations on the continent.

Figure 3.5 Figure 3.5 Total trade volume within the AU Member States, 2022

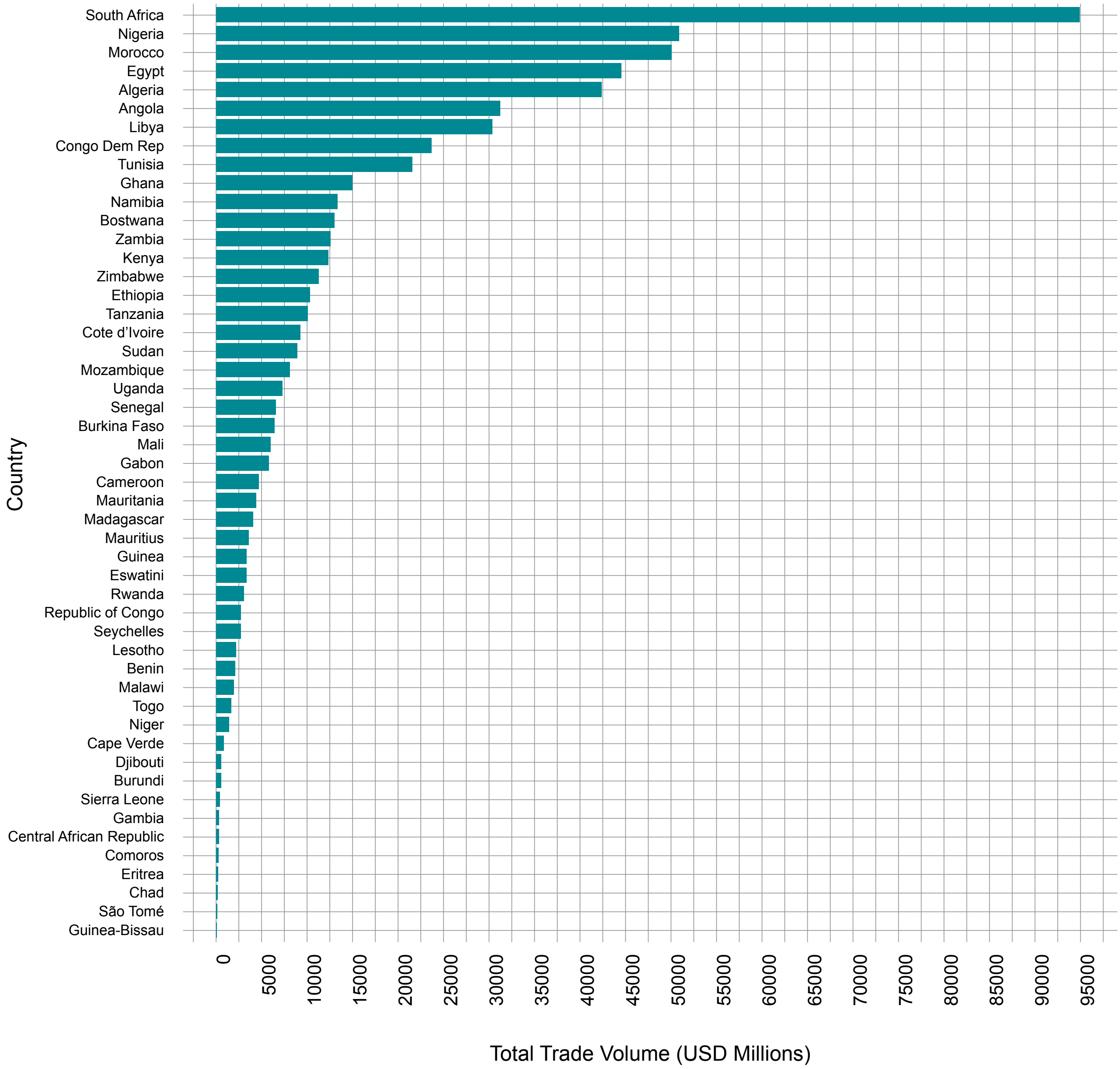
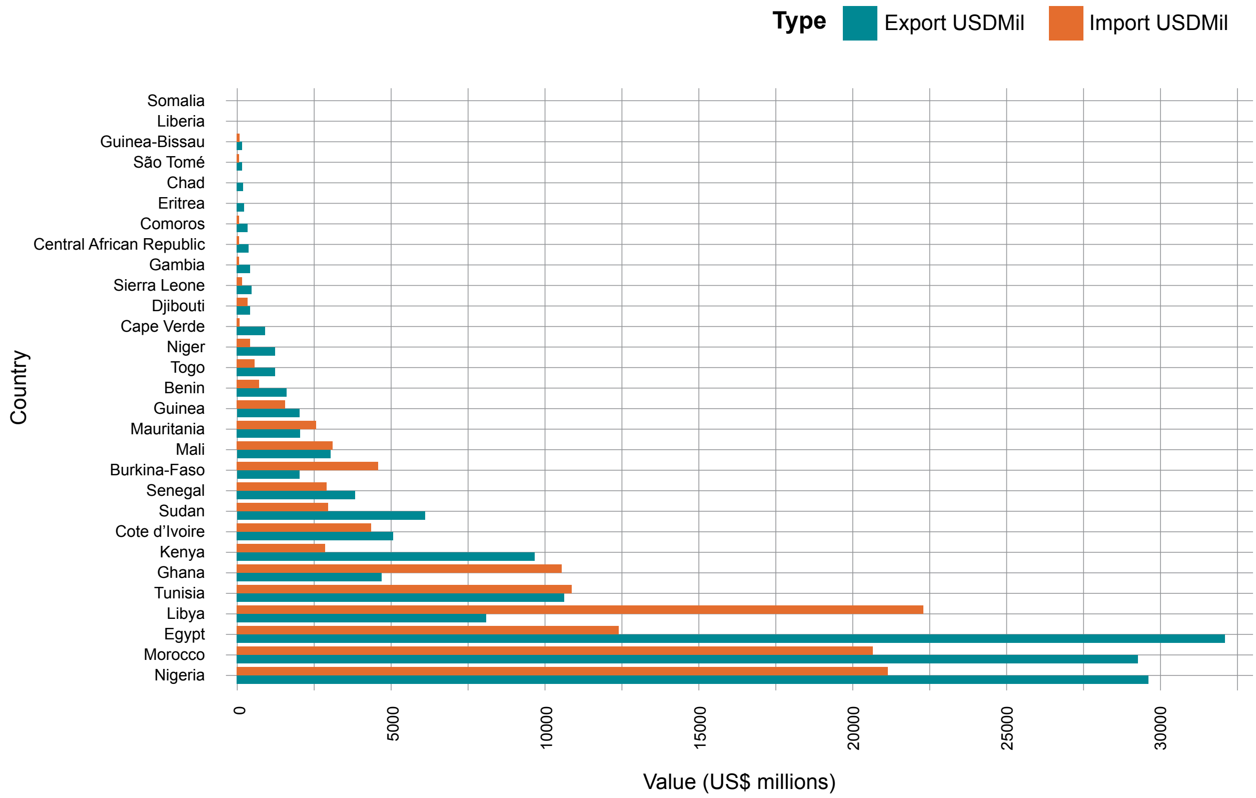


Figure 3.5 shows the Import-Export volumes in the Regional Economic Communities (RECs) of the African Union (AU). The first two graphics show import and export data for the CEN-SAD and COMESA regions.

In the **Community of Sahel-Saharan States** (CEN-SAD) Region as per figure 3.6 overleaf:

- Nigeria, Morocco and Egypt show the highest trade volumes
- Nigeria and Morocco both show significant trade activity above USD20 000-million
- Liberia, Guinea-Bissau show minimal trade activity (below USD2 500-million)
- Somalia shows no data

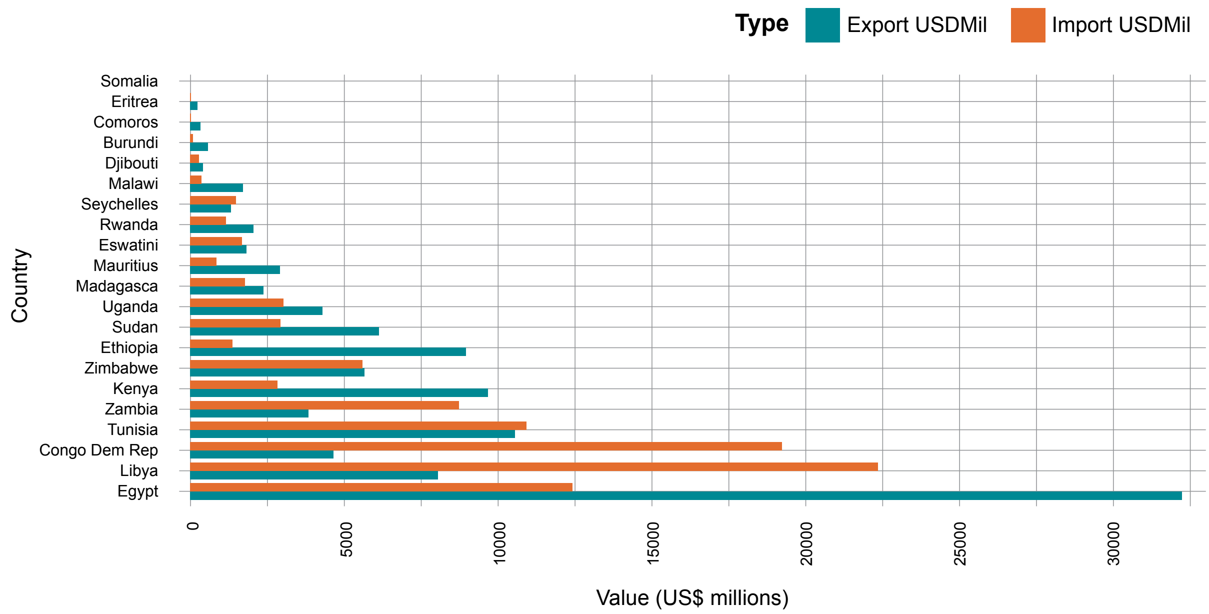
Figure 3.6 Imports and exports in the CEN-SAD region



In the **Common Market for Eastern and Southern Africa** (COMESA) Region as per figure 3.7:

- Egypt dominates with the highest trade volume
- Libya and Congo Democratic Republic show significant trade activity
- Egypt's exports notably exceed its imports
- Eritrea, Comoros and Burundi show minimal trade activity (below USD2 500-million)
- Somalia shows no data

Figure 3.7 Imports and exports in the COMESA region

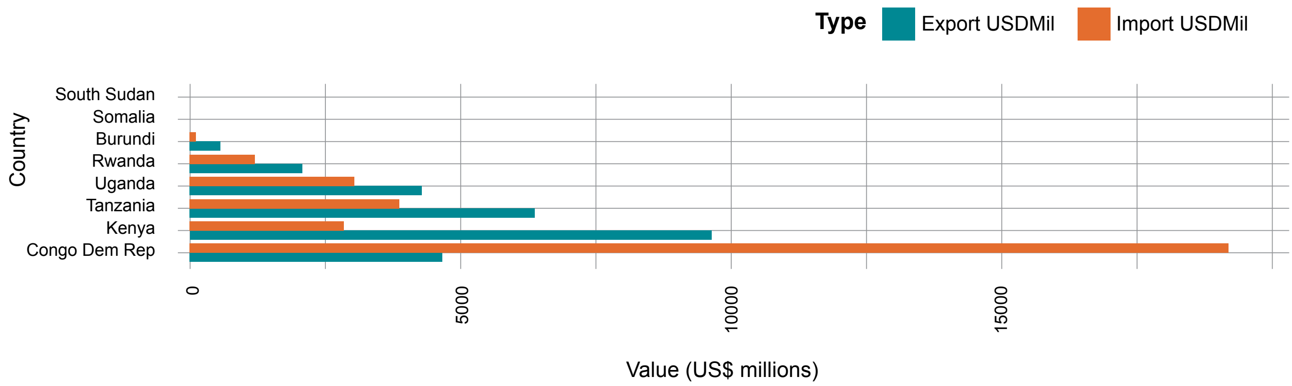


It is also found that most countries in both regions show higher imports than exports and some countries appear in both regional groups (e.g. Egypt, Somalia) as there is overlap in membership.

For the **East African Community** (EAC) region as per figure 3.8:

- The Democratic Republic of Congo shows the highest import value at approximately USD15 000-million, with significantly lower exports
- Kenya has the second-highest trade activity, with exports around USD10 000-million exceeding its imports
- Tanzania and Uganda show moderate levels of trade, with relatively balanced import-export ratios
- Rwanda and Burundi have lower trade volumes and South Sudan and Somalia with no trade activity in the data

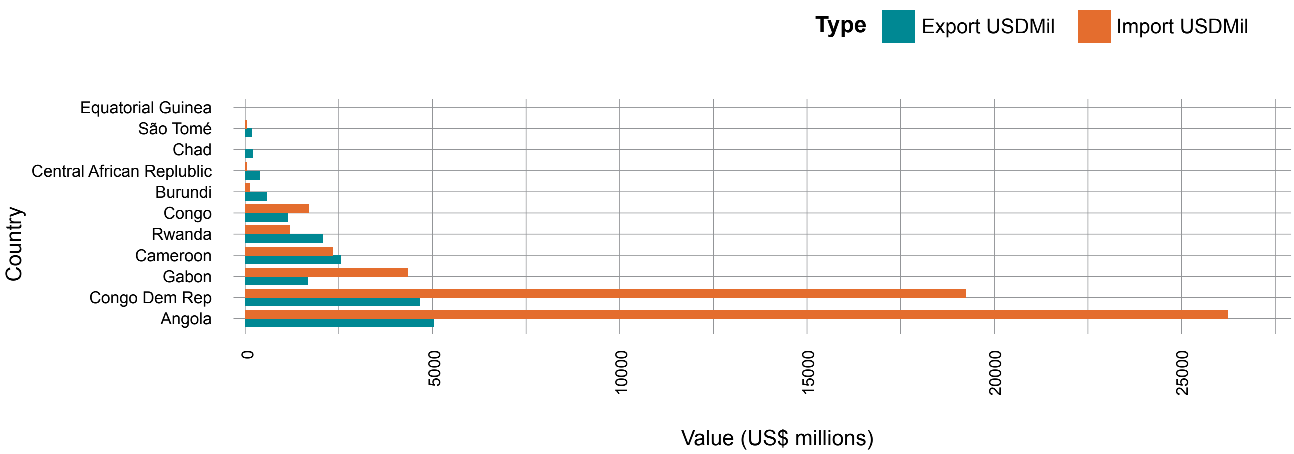
Figure 3.8 Imports and exports in the EAC region



For the **Economic Community of Central African States** (ECCAS) region as per figure 3.9:

- Angola leads with the highest trade volume, with imports around USD25 000-million and lower exports
- The Democratic Republic of Congo is second, showing high imports around USD20 000-million
- Gabon shows moderate trade levels with imports exceeding exports
- Cameroon, Rwanda, Congo and Burundi show lower trade volumes
- São Tomé, Chad and the Central African Republic show minimal trade activity with Equatorial Guinea, with no trade data

Figure 3.9 Import and exports in the ECCAS region

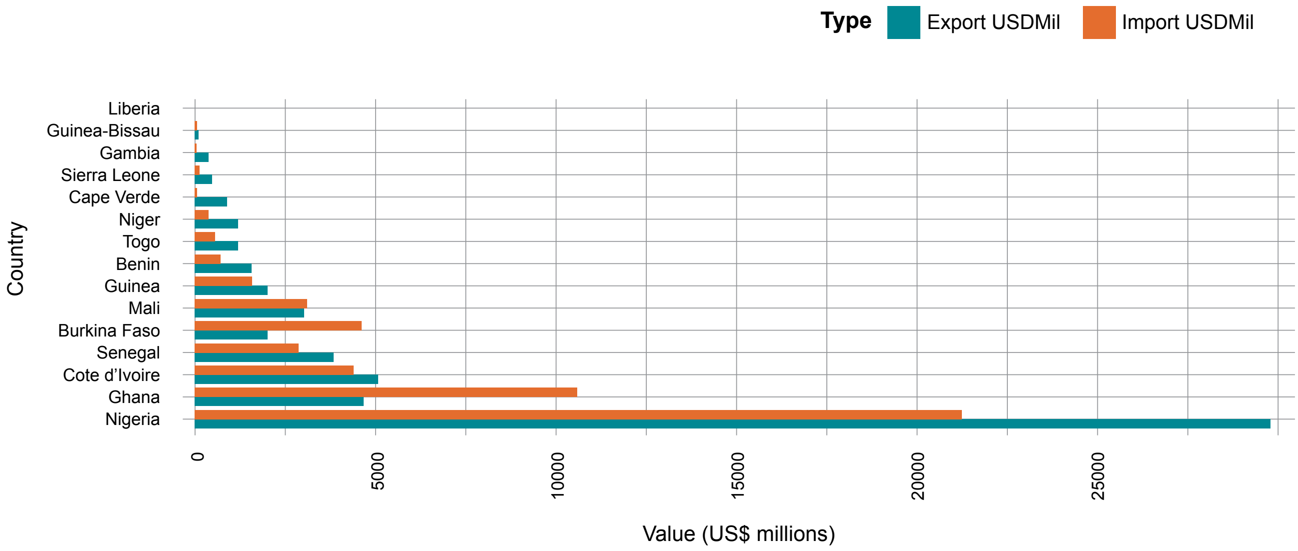


The Democratic Republic of Congo appears in both regional groupings and most countries show higher imports than exports.

In the **Economic Community of West African States** (ECOWAS) region as per figure 3.10:

- Nigeria has the highest trade volume, with exports around USD25 000-million and imports around USD20 000-million
- Ghana is second with significantly lower volumes (imports around USD12 500-million)
- Côte d'Ivoire is third with exports exceeding the imports
- Smaller economies like Guinea-Bissau, Gambia and Sierra Leone show minimal trade volumes, with Liberia showing no trade data

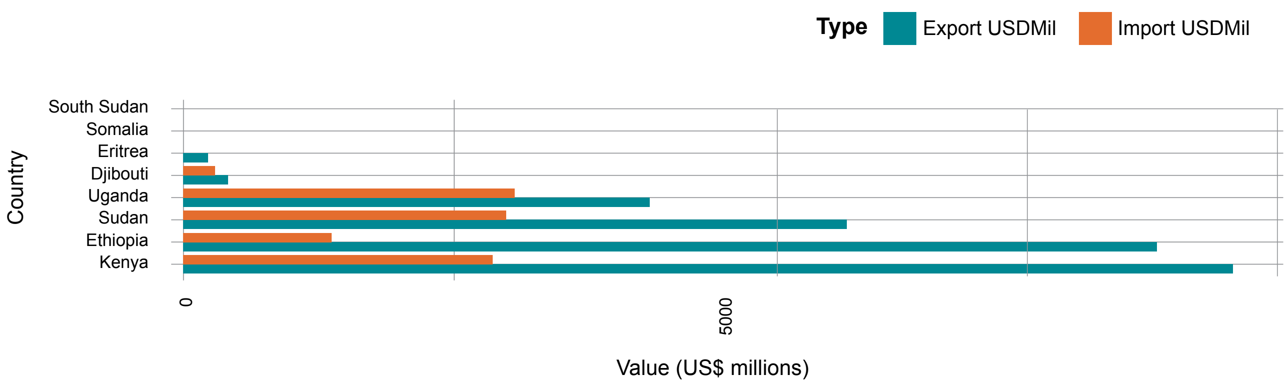
Figure 3.10 Imports and exports in the ECOWAS region – 2022



For the **Intergovernmental Authority on Development** (IGAD) region as per figure 3.11:

- Kenya leads with exports of around USD10 000-million
- Ethiopia shows a strong export performance
- Sudan has a notable trade volume with higher exports than imports
- Somalia and South Sudan show no recorded trade data
- Djibouti and Eritrea have relatively small trade volumes

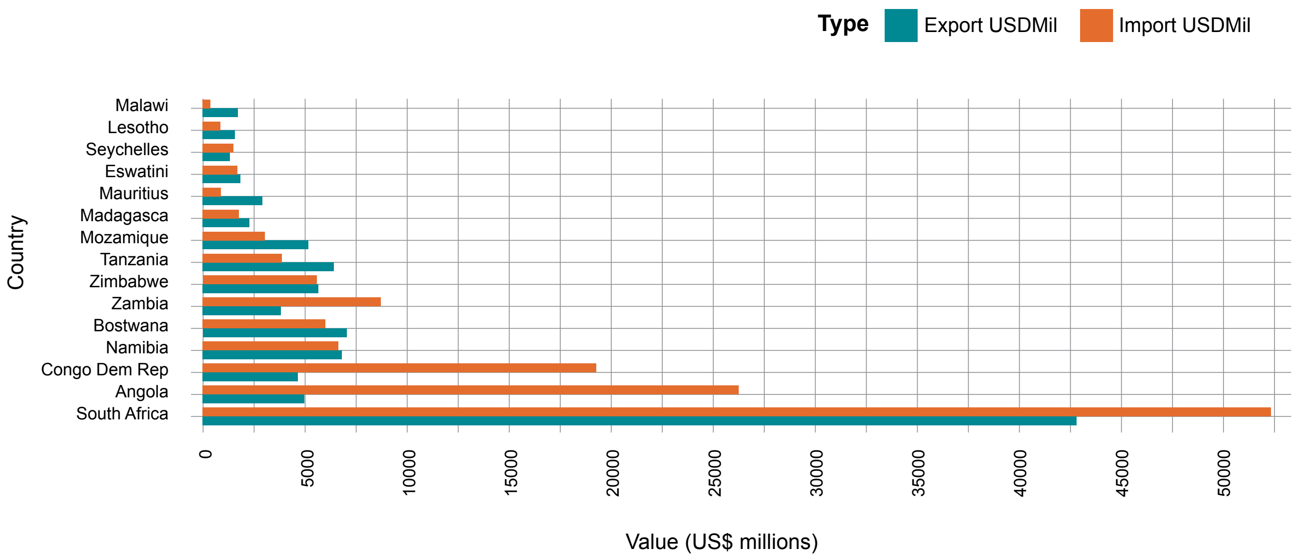
Figure 3.11 Imports and exports in the IGAD region – 2022



For the **Southern African Development Community** (SADC) region as per figure 3.12:

- South Africa has the highest trade values, with both imports and exports around USD45 000-50 000-million
- Angola and the Democratic Republic of Congo show significant trade imbalances, with higher imports than exports
- Smaller economies such as Malawi, Lesotho and Seychelles show much lower trade values

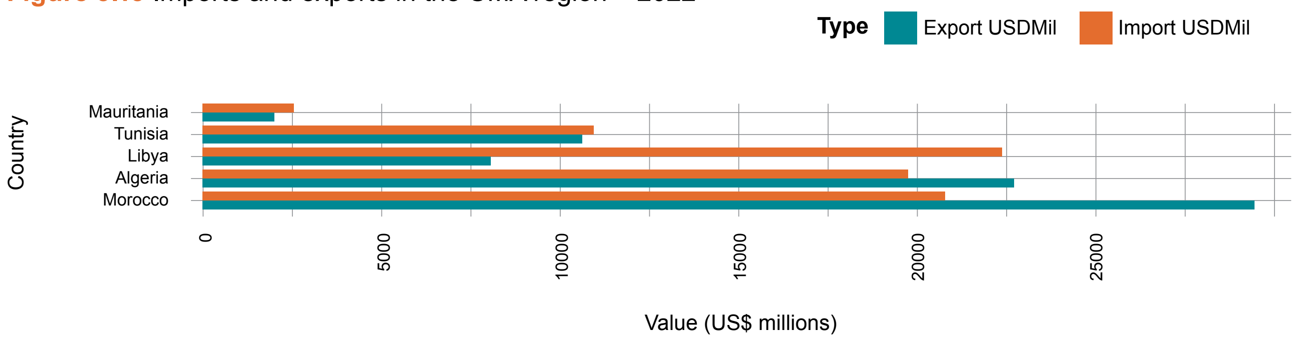
Figure 3.12 Imports and exports in the SADC region



For the **Arab Maghreb Union** (AMU) region as per figure 3.13:

- Morocco shows the highest trade values, with exports exceeding USD25 000-million
- Algeria shows strong trade values with relatively balanced imports and exports
- Libya shows a significant trade imbalance with imports far exceeding exports
- Tunisia shows balanced trade but lower values than its neighbours
- Mauritania has the lowest trade values in the region

Figure 3.13 Imports and exports in the UMA region – 2022



Most countries show trade imbalances, with imports typically exceeding exports.

When it comes to the AU countries' trade partners in terms of imports, the analysis (Table 1) provides insights into their trade relationships and economic dependencies. China is a significant import partner for many African countries, providing machinery, electronics and manufactured goods. It has extensive trade relationships with various African nations. Secondly, the European Union (EU) is also another major import partner for African countries, supplying machinery, vehicles and pharmaceuticals. The US is an important import partner for some African countries, particularly for items like machinery, aircraft and agricultural products. India is emerging as a key import partner for Africa, supplying pharmaceuticals, textiles and machinery. The trade between India and Africa has been increasing in recent years. Countries like the UAE and Saudi Arabia in the Middle Eastern Countries are important partners for African nations, particularly in the oil and gas sector, as well as electronics and machinery.

Lastly, the table reveals the significance of intra-African trade, with some African countries having strong import partnerships within the continent, such as Ethiopia, Mali, Sudan, Uganda, Somalia, Burkina-Faso, DRC and South Africa. And for that, regional trade blocs like ECOWAS, SADC and COMESA promote trade among Member States and the African Continental Free Trade Area (AfCFTA) agreement as the tool at the AU level is one of the flagship projects of the African Union (AU) Agenda 2063, that could significantly boost intra-Africa trade, particularly trade in value-added production and trade across all sectors of Africa's economy. By eliminating barriers to trade in Africa, we can surely build the Africa We Want.

In terms of Exports, at the same time, Table 3.1 highlights the diversity of Africa's trade relationships concerning raw material exports, with China being a predominant destination across many regions. A significant number of African countries export their raw materials primarily to China, indicating China's substantial influence in the African raw materials market. France is also the primary destination for raw materials from countries like Chad and Gabon. India, Italy, Portugal, Spain, the USA and the UAE also emerge as significant destinations for raw materials from specific African countries. The EU countries are a major market for African raw materials, including agricultural products, minerals and energy resources. Many African countries export raw materials to EU nations for processing and consumption and this explains again the poor levels of industrialisation within the Continent.

South Africa serves as a major destination for raw materials from neighbouring countries such as Namibia, Botswana, Mozambique, Zambia, Botswana, Lesotho, Zimbabwe and Eswatini. The US imports raw materials such as oil, minerals and agricultural products from Africa. These materials are crucial for various industries in the US, including energy, manufacturing and agriculture. India is an important destination for African raw materials, especially energy resources like oil and gas, as well as minerals and agricultural products. India's growing economy, like China, drives its demand for raw materials from Africa. Countries like Brazil, Russia, Turkey and South Korea also serve as destinations for African raw materials but in small quantities. These emerging markets have varying demands for different types of raw materials from Africa.

Understanding the main destinations of African raw materials helps in analysing trade flows, economic dependencies and the impact of global demand on Africa's resource-based economies. It also underscores the importance of sustainable resource management and value addition for African countries. Examining the export and import profiles of these nations reveals important insights into their external trade relationships and market dynamics. For example, Nigeria's top exports include petroleum products, cocoa and rubber, while its major imports comprise refined petroleum, wheat and machinery. On the other hand, South Africa is known for exporting precious metals, fruits and vehicles, while importing machinery, electrical equipment and mineral fuels. Understanding these trade patterns can guide strategic decisions on enhancing value addition and seeking competitive advantages in the global market. By capitalising on their strengths and fostering innovation in these pivotal sectors, African countries can optimise their economic potential and elevate their standing on the global stage.

3.2.3 Trade issues and technology intensity

Intra-African trade records frequently understate the amount of trade – partly because of the lack of adequate statistics. According to the World Trade Organisation[4] Africa's exports in 2021 comprised intermediate goods (IGs) made of primary commodities, raw or semi-processed form, destined for global production chains and whose value largely depended on the evolution of prices on global commodity markets. More than 50% of these exports are concentrated among four

4 https://www.wto.org/english/res_e/statis_e/miwi_e/info_note_atig_e.pdf

countries, led by South Africa. The Intra-African IG exports as a share of total IG exports were estimated at 13% in 2021. The corresponding share of IG imports was 11% .

Africa's overall external trade has been increasing, characterised by primary commodities. The value of imports, however, has outweighed exports for some time, resulting in huge trade imbalances for most African countries. The tremendous increase in Africa's import trade has meant that the import bill of most African states has exceeded their export earnings. Imports are primarily necessary for developing manufacturing industries and are mostly limited to mineral fuels, industrial goods, machinery, transport equipment and durable consumer goods. This import-export imbalance indicates a lack of integration of regional supply chains, which could be due to factors such as poor infrastructure, limited product diversification and low levels of investment and financing. The exclusion or partial inclusion of informal cross-border trade in foreign trade statistics is a significant issue in Africa, particularly in trade between neighbouring countries. This factor contributes to underestimations of regional trade, which accounted for 30.9% of Africa's total informal trade exports in 2021. The relatively narrow range of products means that the top 15 IG exports accounted for 54% of Africa's total IG exports in 2021. The imported product portfolio is much more diversified, with the top 15 IG imports accounting for 21% of total IG imports. The category "Other industrial supplies" accounted for 62% of all imported inputs.

African countries primarily engage in trade with industrial partners in Asia and Europe. In 2021, these two regions accounted for 61% of Africa's industrial goods (IG) exports and 68% of its IG imports. The bilateral exchange of industrial inputs between China and Africa experienced significant growth from 2010 to 2021, averaging an annual increase of 10%. In 2021, China emerged as both the leading supplier of industrial goods to African industries and the main export partner, comprising nearly 25% of Africa's total trade in industrial goods. Africa has also been impacted by the changing global trade landscape, influenced by geopolitical shifts, technological advancements and sustainability initiatives. Challenges such as high inflation, economic slowdowns and conflicts have affected trade dynamics, though growth is expected to be gradual.

Digitisation, including the adoption of artificial intelligence (AI), has been a key driver of transformative forces in Africa. This shift towards cleaner energy presents both challenges and opportunities for regional and global trade. The global sustainability agenda offers the continent a chance to address pressing issues while leveraging unique competitive advantages. Consequently, the relationship between trade and technology intensity – and, by extension, innovation – becomes increasingly significant.

To gauge where the African countries are in technology sophistication globally, one can compare the indicated values for 2020 with those of higher-income countries such as Singapore (48.9%) and Malaysia (43.0%). Technology sophistication is a country's technology level, normally expressed in one of the following four levels: high technology, medium technology, medium-low technology and low technology. It is measured in terms of the share of these in their export. At the firm level, technology sophistication is determined by the level of R&D intensity, measured in terms of R&D expenditure divided by the firm's sales. High technology sophistication can be achieved by building technological capabilities of a country's firms. Table 3.2 provide the main picture on top 5 exports and imports. in Africa.

Table 3.1 African countries' trade and technology intensity of exports

S/N	Country	Export (2021)	Import (2021)	Technological sophistication as% percentage of high tech in Export – 2020
1.	Tanzania	Gold ($3.14B), Raw Copper ($815M), Dried Legumes ($321M), Rice ($315M), Raw Copper ($815), Refined Copper ($224M) and Raw Tobacco ($186M).	Machinery, transport equipment and petroleum and chemical products; and for the service sector, the leading is tourism	2.7
2.	South Africa	Platinum ($24.5B), Manganese Ore ($2.9B), Chromium Ore ($1.83B), Precious Metal Ore ($1.78B) and Titanium Ore ($501M)	Refined Petroleum ($7.85B), Crude Petroleum ($5.42B), Motor vehicles; parts and accessories (8701 to 8705) ($3.44B), Cars ($3.25B) and Broadcasting Equipment ($2.43B)	5.6
3.	Kenya	Tea ($1.2B), CutFlowers ($766M), Coffee ($262M), Refined Petroleum ($247M) and Titanium Ore ($194M)	Refined Petroleum ($3.53B), Palm Oil ($1.26B), Packaged Medicaments ($554M), Cars ($549M) and Hot-Rolled Iron ($508M)	5.1
4.	Ghana	Gold ($5.29B), Crude Petroleum ($3.57B), Cocoa Beans ($1.51B), Cocoa Paste ($477M) and Coconuts, Brazil Nuts and Cashews ($477M),	Refined Petroleum ($1B), Cars ($629M), Rice ($552M), Delivery Trucks ($474M) and Coated Flat-Rolled Iron ($422M),	1.5 (2016)
5.	Zambia	Raw Copper ($6.33B), Refined Copper ($2.97B), Gold ($814M), Precious Stones ($280M) and Electricity ($176M)	Refined Petroleum ($600M), Nitrogenous Fertilisers ($278M), Delivery Trucks ($199M), Copper Ore ($193M) and Packaged Medicaments ($188M).	1.4
6.	Senegal	Gold (18.7%), petroleum oils (14.9%), diphosphorus pentaoxide (9.2%), frozen fish (5.7%) and groundnuts (5.4%)	Refined Petroleum ($2.39B), Rice ($476M), Crude Petroleum ($463M), Cars ($361M) and Packaged Medicaments ($330M)	0.7
7.	Nigeria	Crude Petroleum ($41.8B), Petroleum Gas ($8.52B), Special Purpose Ships ($1.25B), Cocoa Beans ($779M) and Refined Petroleum ($667M)	Refined petroleum ($11.3B), Wheat ($3.32B), Cars ($2.42B), Packaged Medicaments ($972M) and Broadcasting Equipment ($934M)	6.9
8.	Burkina Faso	Gold ($7.71B), Raw Cotton ($471M), Zinc Ore ($314M), Other Oily Seeds ($112M) and Coconuts, Brazil Nuts and Cashews ($101M)	Refined Petroleum ($578M), Packaged Medicaments ($166M), Electricity ($147M), Cement ($127M) and Petroleum Gas ($101M)	-
9.	Egypt	Refined Petroleum ($4.77B), Crude Petroleum ($3.69B), Petroleum Gas ($3.5B), Nitrogenous Fertilisers ($1.7B) and Gold ($1.16B)	Refined Petroleum ($5.63B), Wheat ($4.53B), Cars ($3.98B), Crude Petroleum ($3.13B) and Corn ($2.18B),	2.7
10	Tunisia	Textiles, agricultural products (olive oil, citrus, vegetables), phosphates and chemicals, mechanical and electrical goods and hydrocarbons	Machinery and equipment, chemicals, fuel and food	7.2 (2021)

Source: The Observatory of Economic Complexity | Imports and Trade Partners | (oec.world)
https://oec.world/en/profile/country/bfa

Table 3.2 African countries' top five products (HS 6-digit level) and top five export-import partners in billion

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Algeria 2017	- Petroleum oils/bituminous oils $12,7B - Natural gas in gaseous state $7,1B - Petroleum Oils, etc., (excl. crude) $6,4B - Natural gas, liquefied $3,6B - Propane, liquefied $1,9B	- Petroleum oils, etc., (excl. crude); preparation $1,6B - Spelt, common wheat/meslin $ 1,2B - Raw cane sugar, in solid form $0,97B - Automobiles/reciprocating piston di. engine $0,86B - Semi-fin prod,i/nas,rect/sq cross-sect cntg by $),79B	Italy 16% | $S5,6B France 12,59% | 4,4B Spain 11.66% | 4,1B USA 9,85% | 3,46B Brazil 6.05% | 2,2B	China 18,06% | 8,3B France 9,33% | 4,2B Italy 8.15% | 3.75B Germany 7% | 3,2B Spain 6.8% | 3.1B
Angola 2022	- Petroleum oils/bituminous oils $40,3B - Natural gas, liquefied, $6,08B - Diamonds industry. unworked/simply sawn $1,98B - Petro oils, etc.,excl. Crude/preparation $0,48B - Floating/submersible drilling/production $0,44B	- Petroleum oils, etc., (excl. crude); preparation $3,9B - Durum wheat $0.38b - Semi-milled or wholly milled rice $0.34b - Frozen cuts and offal of chicken (excl. livers) $0.34 - Palm oil (excl. crude) and liquid fractions $0.33B	China 42.72% | $21,9B India 10.03% | 5,1B France 7.12% | 3,65B Netherlands 6.68% | 3,42B Spain 4.33% | 2,2B	China 16,04% | 2.85B Portugal 10.75% | 1,91B Korea 9.22% | 1,64B Netherlands 6.83% | 1,2B India 6.08% | 1.08B
Benin 2022	- Cotton, not carded or combed $0,58 - Petroleum oils, etc., (excl. crude)/ preparat. $0,038B - Cashew nuts, fresh or dried $0,033B - Cotton seeds $ 0.029B - Oil-cake/other solid residues cotton seed $0.028B	- Semi-milled or wholly milled rice 0,648B - Petroleum oils, etc., (excl. crude); preparation $0,549B - Mineral or chemical fertilisers with nitrogen $0,116B - Other medicaments of mixed/unmixed products $0,089B - Imported Electrical energy $0.080B	Bangladesh. 45.15% | $0.406 India 11.99% | $0.108B China 6.17% | $0.55B Egypt 4.44% | $0.4B Pakistan 4.17% | $0.37B	India 15.34% | $0.59 China 15.15% | $0.54 France 8.00% | $0.308 UAE 6.88% | $0,265B Nigeria 4.83% | $0,18B
Botswana 2022	- Diamonds non-industrial unworked/simply sawn $5,83B - Diamonds non-industrial nes excl. mounted $1,475B - Copper ores and concentrates $0,32B - Ignition wiring sets/other wiring sets $0.117B - Live pure-bred breeding bovine animals $0.074B	- Diamonds non-industrial unworked or simply sawn $1.42B - Petroleum oils, etc., (excl. crude); preparation $ 1.35B - Diamonds non-industrial nes excluding mounted $0.55B - Diamonds unsorted, whether worked $0.23B - Electrical energy $0.10B	- UAE 27.1% | $ 2,28B - Belgium 18.97% | $ 1.59B - India 15.21% | $1.28B - Botswana 10.09% | $ 0.84 - Hong Kong China 6.5% |$0.55B	- Africa 62.66% | $5.08B - Namibia 7.13% | $0.57B - Belgium 5.79% | $047B - India 4.46% | $0.36B - Canada 3.62% | $0.29

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Burkina Faso 2022	- Gold in other semi-manufactured forms, non-monetary. $3,36B - Cotton, not carded or combed $0.47B - Cashew nuts, fresh or dried $0.14B - Portland cement (excl. white) $0.081B - Sesamum seeds $0.067B	- Petroleum oils, etc., (excl. crude); preparation $1.81B - Other medicaments, mixed/unmixed products $0.19B - Cement clinkers $0.17B - Electrical energy $0.136B - Butanes, liquefied $0.12B	Switzerland 68.86% | $ 3.13B Mali 6.63% | $ 0.3B UAE 4.27% | $ 0.19B Singapore 3.77% | $0.17B Cote d'Ivoire 3.69% | $0.168B	China 12.98% | $0.73B Cote d'Ivoire 9.25% | $0.59 France 9.25% | $0.5B Russia 7.7% | $0.439 India 6.45% | $0.36B
Burundi 2022	- Coffee, not roasted or decaffeinated $0.053B - Gold in unwrought forms, non-monetary $0.051 - Black tea/fermented & partly fermented $0.022B - Cigarettes containing tobacco $0.010B - Beer made from malt $0.009B	- Petroleum oils, etc., (excl. crude)/ preparation $0.29B - Superphosphates $0.079B - Other medicaments of mixed/unmixed products $0.043B - Spelt, common wheat and meslin $0.034B - Portland cement (excl. white) $0.027B	UAE 28.03% | $0.058B DRC 18.64% | $0.039B Switzerland 9.47% | $0.020B Belgium 8.03% | $0.017B Pakistan 4.88% | $0.010B	Saudi Arabia 14.69% | $0.18B China 14.14% | $0.178B UAE 13.88% | $0.175B Tanzania 9.07% | $0.114B India 8.47% | $0.107B
Cameroon 2021	- Petroleum oils and oils obtained from bituminous $1.74B - Cocoa beans, whole or broken, raw or roasted $0.48B - Natural gas, liquefied $0.456B - Wood, nes sawn or chipped lengthwise, sliced $0.30B - Cotton, not carded or combed $0.257B	- Petroleum oils, etc., (excl. crude); preparation, worth 1.105] B - Semi-milled or wholly milled rice $0.361B - Spelt, common wheat and meslin $0.329B - Other medicaments of mixed or unmixed products $0.245 - Frozen fish, nes $0.207B	China 25.89% | $1.11B Netherlands 12.41% | $0.53B India 9.67% | $0.41B Italy 7.15% | $0.30B Spain 6.11% | $0.26B	China 25.89% | $1.11B Netherlands 12.41% | $0.53B India 9.67% | $0.41B Italy 7.15% | $0.30B Spain 6.11% | $0.26B
Cabo Verde 2022	- Petroleum oils, etc., (excl. crude); preparation $0.18B - Cargo containers designed to be carried by one $0.032B - Prepared/preserved mackerel (excl. minced) $0.013B - Prepared/preserved tuna/skipjack/bonito $0.012B - Prepared/preserved fish (excl. minced), nes $0.007B	- Petroleum oils, etc., (excl. crude); preparation $0.18B - Cargo containers designed to be carried by one $0.032B - Prepared/preserved mackerel (excl. minced) $0.013B - Prepared/preserved tuna/skipjack/ bonito $0.012B - Prepared/preserved fish (excl. minced), nes $0.007B	Unspecified 44.84% | $0.139B Spain 13,88% | $0.043B Portugal 11.94% | $0.037B Netherlands 6.85% | $0.021B Togo 6.06% | $0.019B	Portugal 28.66% | $0.50B Netherlands 12.72% | $0.225B UAE 10.70% | $0.19B India 8.73% | $0.155B Belgium 6.65% | $0.118B

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Central African Republic (2022)	- Gold in unwrought forms non-monetary, 50,253.39 ($ Thousands). - Drive axles with differential for motor vehicle, 14,889.93 ($ Thousands). - Diamonds industrial unworked or simply sawn, cl, 14,079.64 ($ Thousands). - Signal generators, 8,057.76 ($ Thousands). - Tanks and other armoured fighting vehicles, mot, 7,622.33 ($ Thousands).	- Hydraulic power engines & motors linear acting, 75,081.74 ($ Thousands). - Aircraft nes of an unladen weight not exceeding 39,114.35 ($ Thousands). - Other medicaments of mixed or unmixed products, 38,942.38 ($ Thousands). - Prefabricated buildings, 29,675.99 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 25,557.47 ($ Thousands).	United Arab Emirates $47 M, 40.92% Pakistan $2 3M, 19.79% Italy $15M, 12.60% France $10 M, 9.00% Cameroon $ 8M, 7.19%	Cameroon $25 1M, 40.19% United States $6 0M, 9.65% France $50 M, 8.07% China $50 M, 7.95% Belgium $21 M, 3.43%
Chad	No data	No data	No data	No data
Congo, Dem. Rep. 2022	- Copper cathodes/sections of cathodes unw $411,8B - Cobalt oxides /hydroxides; commercial cobalt, $2,15B - Refined copper products, unwrought, nes, 696,467.78 ($ Thousands). - Copper unrefined, copper anodes for electrolytic, 190,220.33 ($ Thousands). - Cobalt and articles thereof, nes, 162,986.78 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 2,619,405.00 ($ Thousands). - Crude or unrefined sulphur, 908,326.03 ($ Thousands). - Sulphuric acid; oleum, 254,913.86 ($ Thousands). - Magnesia and other magnesium oxide, 228,544.87 ($ Thousands). - Durum wheat, 187,812.80 ($ Thousands).	China $7,388 M, 47.14% Singapore $1,365 M, 8.71% Hong Kong, China $1,24 4M, 7.94% Tanzania $1,171 M, 7.47% South Africa $1,160 M, 7.40%	China $3,027 M, 26.54% South Africa $1,307 M, 11.46% United Arab Emirates $1,141 M, w10.00% India $654 M,5.74% Tanzania $508 M, 4.45%
Congo, Rep. 2021	- Petroleum oils and oils obtained from bituminous, 1,072,025.91 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 216,583.22 ($ Thousands). - Keruing, Ramin, Kapur, Teak, Jongkong, Merbau, 168,235.91 ($ Thousands). - Wood, nes sawn or chipped lengthwise, sliced or, 163,538.83 ($ Thousands). - Floating or submersible drilling or production, 155,785.92 ($ Thousands).	- Frozen cuts and offal of chicken (excl. livers), 113,881.92 ($ Thousands). - Floating or submersible drilling or production, 104,416.15 ($ Thousands). - Spelt, common wheat and meslin, 95,349.94 ($ Thousands). - Cargo vessels nes and other vessels for the trade, 94,545.35 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 91,199.30 ($ Thousands).	China $1,081 M, 45.76% Cote d'Ivoire $202 M, 8.56% Togo $178 M, 7.53% Cameroon $127 M, 5.38% Gabon $94 M, 3.99%	China $460 M, 19.57% France $293 M, 12.46% Belgium $211 M, 8.99% Russian Federation $104 M, 4.44% United States $98 M, 4.15%

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Cote d'Ivoire 2022	- Cocoa beans, whole or broken, raw or roasted, 3,211,635.27 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 2,029,832.35 ($ Thousands). - Technically specified natural rubber, in primary, 1,553,398.51 ($ Thousands). - Gold in unwrought forms non-monetary, 1,476,971.76 ($ Thousands). - Cashew nuts, fresh or dried, 988,881.82 ($ Thousands).	- Petroleum oils and oils obtained from bituminous, 2,400,384.77 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 1,906,334.10 ($ Thousands). - Semi-milled or wholly milled rice, 639,356.49 ($ Thousands). - Floating or submersible drilling or production, 590,117.31 ($ Thousands). - Butanes, liquefied, 486,811.30 ($ Thousands).	Mali $1,463 M, 8.91% Netherlands $1,426 M, 8.68% Switzerland $1,325 M, 8.06% United States $878 M, 5.34% Burkina Faso $852 M, 5.19%	China $2,575 M, 14.40% Nigeria $2,167 M, 12.12% France $1,195 M, 6.68% India $932 M, 5.21% United States $832 M, 4.65%
Djibouti 2009	- Conveyor... belting, of vulcanised rubber of tr, 44,998.87 ($ Thousands). - Trucks nes, 38,917.75 ($ Thousands). - Parts for rollers and other soil preparation or 31,526.25 ($ Thousands). - Milk and cream in solid forms of >1.5% fat, swe, 28,108.28 ($ Thousands). - Parts and accessories of bodies nes for motor v, 25,305.09 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 40,944.33 ($ Thousands). - Radar apparatus, 33,410.69 ($ Thousands). - Automobiles with diesel engines displacing more, 23,274.26 ($ Thousands). - Prefabricated buildings, 14,379.01 ($ Thousands). - Other fruit, fresh, nes, 13,849.60 ($ Thousands).	Ethiopia (excludes Eritrea) $129 M, 35.35% France $73 M,20.08% Somalia $43 M, 11.87% Brazil $32 M, 8.67% Qatar $23 M, 6.29%	France $198 M, 30.50% United Arab Emirates $120 M, 18.48% Saudi Arabia $39 M, 5.98% Japan $35 M, 5.47% Ethiopia (excludes Eritrea) $32 M, 5.01%
Egypt 2022	- Natural gas, liquefied, 9,861,231.00 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 5,121,044.65 ($ Thousands). - Petroleum oils and oils obtained from bituminous, 3,202,780.00 ($ Thousands). - Urea, 2,511,835.87 ($ Thousands). - Gold in unwrought forms non-monetary, 1,596,788.47 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 5,804,520.54 ($ Thousands). - Petroleum oils and oils obtained from bituminous, 4,627,680.00 ($ Thousands). - Durum wheat, 4,086,168.18 ($ Thousands). - Maise (excl. seed), 3,048,694.55 ($ Thousands). - Soya beans, 2,788,937.01 ($ Thousands).	Turkey 7.60% | $3,96M, 7.60 Spain $3,850 M, 7.39% Italy $3,382 M, 6.49% Saudi Arabia $2,516 M, 4.83% United States $2,301 M, 4.41%	China $14,764 M, 15.35% Saudi Arabia $7,886 M, 8.20% United States $6,953 M, 7.23% Russian Federation $4,273 M, 4.44% Germany $4,112 M, 4.28%

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Eswatini 2021	- Mixtures of odoriferous substances, for the food, 618,713.39 ($ Thousands). - Raw cane sugar, in solid form, 384,223.90 ($ Thousands). - Chemical products and residual products of chemistry, 265,777.97 ($ Thousands). - Coniferous wood sawn or chipped lengthwise, sli, 86,378.52 ($ Thousands). - Women's or girls' trousers, breeches, etc., of c, 41,942.17 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 183,619.61 ($ Thousands). - Electrical energy, 154,849.63 ($ Thousands). - Electro-diagnostic apparatus, nes, 48,565.59 ($ Thousands). - Bleached plain cotton weave, with <85% cotton,, 45,486.17 ($ Thousands). - Other medicaments of mixed or unmixed products, 43,174.38 ($ Thousands).	South Africa $1,405 M, 67.94% Kenya $116 M, 5.63% Nigeria $80 M, 3.85% Mozambique $70 M, 3.40% Zimbabwe $51 M, 2.45%	South Africa $1,537 M, 72.40% China $206 M, 9.71% India $57 M, 2.68% Mozambique $34 M, 1.60% United States $32 M, 1.53%
Fm Sudan 2011	- Petroleum oils and oils obtained from bituminous, 7,200,561.22 ($ Thousands). - Gold in unwrought forms non-monetary, 716,882.47 ($ Thousands). - Live sheep, 250,211.65 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 205,596.54 ($ Thousands). - Sesamum seeds, 186,357.65 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 821,659.65 ($ Thousands). - Durum wheat, 580,077.99 ($ Thousands). - Raw cane sugar, in solid form, 382,513.28 ($ Thousands). - Bituminous or oil shale and tar sands, 313,175.71 ($ Thousands). - Plates..., of polymers of propylene, not reinfo, 179,306.80 ($ Thousands).	China $6,323 M, 70.40% United Arab Emirates $944 M, 10.50% Japan $315 M, 3.51% Ethiopia (excludes Eritrea) $282 M, 3.14% Saudi Arabia $260 M, 2.89%	China $2,067 M, 21.66% United Arab Emirates $822 M, 8.61% Saudi Arabia $772 M, 8.09% India $623 M, 6.52% Japan $592 M, 6.20%
Gabon 2021	- Petroleum oils and oils obtained from bituminous, 3,932,465.18 ($ Thousands). - Floating or submersible drilling or production, 1,022,731.29 ($ Thousands). - Floating docks and vessels which perform special, 648,698.04 ($ Thousands). - Manganese ores and concentrates, with a manganese, 537,897.09 ($ Thousands). - Wood, nes sawn or chipped lengthwise, sliced or, 454,735.68 ($ Thousands).	- Floating or submersible drilling or production, 659,941.26 ($ Thousands). - Floating docks and vessels which perform special, 394,856.77 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 96,144.20 ($ Thousands). - Frozen cuts and offal of chicken (excl. livers), 91,988.33 ($ Thousands). - Other medicaments of mixed or unmixed products, 78,220.49 ($ Thousands).	China is worth $1,969 M, 24.52% India is worth $861 M, 10.72% Cameroon is worth $646 M, 8.04% Congo, Rep. worth $453 M, 5.64% Korea, Rep. worth $408 M, 5.08%	France $513 M, 14.06% Singapore $441 M, 12.10% China $413 M, 11.33% United States $254 M, 6.97% United Arab Emirates $120 M, 3.29%

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Gambia, The 2021	- Petroleum oils, etc., (excl. crude); preparation, 12,056.24 ($ Thousands). - Rye, worth 3,726.98 ($ Thousands). - Shelled groundnuts, not roasted or otherwise c, 2,033.68 ($ Thousands). - Drilling or morticing machine for working wood /cork, 1,376.27 ($ Thousands). - Cashew nuts, fresh or dried, 1,327.87 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 270,935.36 ($ Thousands). - Automobiles with diesel engines displacing more, 41,122.49 ($ Thousands). - Broken rice, 38,337.04 ($ Thousands). - Linseed oil (excl. crude) and fractions, 20,904.21 ($ Thousands). - Automobiles with reciprocating piston engine di, 19,448.44 ($ Thousands).	Mali $12 M, 44.69% China $8 M, 29.07% Senegal $3 M, 10.93% Guinea-Bissau $1 M, 4.47% India $1 M, 3.66%	Togo $180 M, 25.45% Cote d'Ivoire $88 M, 12.38% China $54 M, 7.62% Denmark $42 M, 5.97% India $40 M, 5.64%
Ghana 2022	- Gold in other semi-manufactured forms, non-monetary, 6,484,541.86 ($ Thousands). - Petroleum oils and oils obtained from bituminous, 5,188,804.24 ($ Thousands). - Cocoa beans, whole or broken, raw or roasted, 1,261,449.74 ($ Thousands). - Cocoa paste, not defatted, 414,306.61 ($ Thousands). - Cashew nuts, fresh or dried, 289,948.04 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 4,572,987.44 ($ Thousands). - Automobiles with reciprocating piston engine di, 380,017.25 ($ Thousands). - Cement clinkers, 373,542.07 ($ Thousands). - Other worked grains of other cereals, nes, 257,291.31 ($ Thousands). - Frozen cuts and offal of chicken (excl. livers), 198,100.78 ($ Thousands).	Switzerland $3,152 M, 18.14% China $2,201 M, 12.67% Canada $1,829 M, 10.53% South Africa $1,802 M, 10.37% India $1,688 M, 9.71%	China $3,187 M, 17.74% United Kingdom $2,410 M, 13.42% Netherlands $1,351 M, share of 7.52% United States $1,073 M, 5.97% India is worth $959 M, share of 5.34%
Guinea 2016	- Gold in unwrought forms non-monetary, 1,351,029.32 ($ Thousands). - Aluminium ores and concentrates, 615,059.01 ($ Thousands). - Gold in other semi-manufactured forms, non-monetary, 176,053.53 ($ Thousands). - Diamonds, non-industrial unworked or simply sawn, 33,377.60 ($ Thousands). - Cashew nuts, fresh or dried, 28,532.99 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 470,837.12 ($ Thousands). - Dates, fresh or dried, 333,223.44 ($ Thousands). - Broken rice, 213,743.86 ($ Thousands). - Dump trucks designed for off-highway use, 175,308.36 ($ Thousands). - Other medicaments of mixed or unmixed products, 158,198.65 ($ Thousands).	United Arab Emirates $660 M, 27.57% Ghana $367 M, 15.34% India $217 M, 9.07% Switzerland $184 M, 7.68% France $145 M, 6.07%	China $582 M, 16.81% United Arab Emirates $465 M, 13.42% Netherlands $444 M, 12.81% India $288 M, 8.31% France $243 M, 7.02%

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Guinea-Bissau 2018	- Cashew nuts, fresh or dried, 167,802.63 ($ Thousands). - Wood, nes sawn or chipped lengthwise, sliced or, 12,275.66 ($ Thousands). - Oak (Quercus spp.) wood, sawn/chipped lengthwise, 1,807.79 ($ Thousands).	- Broken rice 28,961.20 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation 27,774.87 ($ Thousands). - Portland cement (excl. white) 7,856.69 ($ Thousands). - Wheat or meslin flour 6,923.09 ($ Thousands). - Other fermented beverages (for example, cider, 5,110.25 ($ Thousands).	India $108 M, 44.17% China $71 M, 29.14% Singapore $44 M, 17.85% Vietnam $15 M, 6.13% United Arab Emirates $4 M, 1.70%	Portugal $63 M, 38.27% Senegal $28 M, 17.11% Pakistan $14 M, 8.72% China $9 M, 5.62% Netherlands $9 M, 5.27%
Kenya 2022	- Black tea (fermented) and partly fermented tea; $1,4B - Fresh cut flowers and buds; $0,6B - Petroleum oils, etc., (excl. crude); preparation; $0,4B - Coffee, not roasted or decaffeinated; $0,31B - Titanium ores and concentrates; $0,25B	- Fresh cut flowers and buds; $0,96B - Spelt, common wheat and meslin; $0,6B - Other medicaments of mixed or unmixed products; $0,5B - Flat rild prod, i/nas, in coil, hr, =>600mm w, l; $0,45B	China 18,20% | $3840 United Arab Emirates 16.38% | $3456B India10,05% | $2121B Saudi Arabia 4,91% | $1035B Malaysia 4,85% | 1023B	Uganda 11,13% | $0,82B United States 9,21% | $0,68B Netherlands 8,02% | $0,59B Pakistan 7.4% | $0,544 Tanzania 6,51% | $0,48
Lesotho 2022	- Diamonds, non-industrial unworked or simply sawn; $0,17B. - Mineral waters and aerated waters, unsweetened; $0,08B. - Women's or girls' trousers, etc., of synthetic, $0,08B. - Men's or boys' trousers, breeches, etc., of cotton, $0,072. - T-shirts, singlets, etc., of other textiles, nes, $0,48B	- Petroleum oils, etc., (excl. crude); preparation, $0,2B - Cotton not carded or combed, $0.094. - Knitted or crocheted fabrics, =<30cm wide, non -, $0,052B. - Electrical energy, $0,042B. - Maise (corn) flour, $0,036B.	South Africa 50.38% | $0,4B USA 26.21% | $0,2B Belgium 19.15% | $0,17B Eswatini 1.26% | $0,01B Germany 0,78% | $0,007B	South Africa 77,36% | $1.5B, China 6.21% | $0,12B, Other Asia, nes 4,18% | $0,008B. Zimbabwe 3.83% | $0,072B India 1.70% | $0,032B.

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Libya 2019	- Petroleum oils and oils; $24B - Natural gas, liquefied; $1B - Gold in unwrought forms, non-monetary; $1B - Petroleum oils, etc., (excl. crude); preparation; $0,85B - Petroleum gases and other gaseous hydrocarbons; $0,8B	- Petroleum oils, etc., (excl. crude); preparation; $2B - Automobiles with reciprocating piston engine di; $0,69B - Transmission apparatus, for radiotelephone incorporation; $0,62B - Cigarettes containing tobacco; $0,43B - Art. of jewellery and pts thereof of/o prec mtl, $0,28B	Italy 33.23% | $9,7B China 22.46% | $6,6B Spain 11.64% | $3,4B France 5% | $1,5B United Arab Emirates 4.13% | $1,2B	China15,66% | $2.5B Turkey 13.21% | $2,01B Italy 8.88% | $1,4B United Arab Emirates 8.65%| $1,4B Egypt, Arab Rep. 5.30% | $0,8B
Madagascar 2022	- Nickel unwrought, not alloyed; $0,9B. - Vanilla, $0,5B. - Cloves (whole fruit, cloves and stems); $0,29B. - Cobalt, unwrought, matte and other intermediate products; $0,21B. - Titanium ores and concentrates; $0,14B	- Petroleum oils, etc., (excl. crude); preparation; $0,99B ; - Semi-milled or wholly milled rice; $0,31B. - Crude or unrefined sulphur; $0,15B. - Crude palm oil; $0,14B. - Bituminous coal, not agglomerated; $0,13B	United States 15.75% | $0,586B. France worth 15.44% | $0,575B. China 13.92% | $0.518B Japan 11.92% | $0,444B. Korea, Rep. 4.23% $0.157B	China 18.58% | $1B. Oman 12.71% | $0,713B. India 9.35% | $0,525B. France 9.04% | $0,507B. South Africa 5.88% | $0.33,
Malawi 2022	Tobacco partly or wholly stemmed/stripped, 362,628.38 ($ Thousands). Shelled groundnuts not roasted or otherwise, 80,511.80 ($ Thousands). Black tea (fermented) and partly fermented tea, 76,052.03 ($ Thousands). Tobacco not stemmed/stripped, 43,022.25 ($ Thousands). Dried leguminous vegetables, shelled, nes, 38,582.70 ($ Thousands).	Petroleum oils, etc., (excl. crude); preparation 267,111.05 ($ Thousands). Urea, worth 102,288.25 ($ Thousands). Mineral or chemical fertilisers with nitrogen, 46,582.27 ($ Thousands). Worn clothing and other worn articles, 35,227.08 ($ Thousands). Palm oil (excl. crude) and liquid fractions 34,035.69 ($ Thousands).	Belgium $144 M, 15.98% Tanzania $85 M, 9.42% Kenya $62 M, 6.89% South Africa $58 M, 6.45% Zimbabwe $48 M, 5.33%	China $261 M, 16.48% United Arab Emirates $222 M, 14.01% South Africa $222 M, 14.00% Kuwait $118 M, 7.41% India $87 M, 5.51%

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Mali 2019	- Gold in unwrought forms non-monetary 2,657,101.42 ($ Thousands). - Cotton carded or combed 421,646.57 ($ Thousands). - Live bovine animals, other than pure-bred breed 93,538.29 ($ Thousands). - Live pure-bred breeding bovine animals 56,686.25 ($ Thousands). - Live sheep 52,661.24 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation 1,361,243.58 ($ Thousands). - Other medicaments of mixed or unmixed products, 172,604.94 ($ Thousands). - Portland cement (excl. white) 171,746.36 ($ Thousands). - Spelt, common wheat and meslin 94,738.12 ($ Thousands). - Photosensitive semiconductor devices,photovolta 78,322.44 ($ Thousands).	South Africa $1,328 M, 36.46% Switzerland $1,298 M, 35.63% Bangladesh $259 M, 7.10% Cote d'Ivoire $154 M, 4.24% Burkina Faso $101 M, 2.76%	Senegal $1,136 M, 22.50% China $796 M, 15.77% Cote d'Ivoire $536 M, 10.62% France $401 M, 7.94% India $156 M, 3.09%
Mauritania 2022	- Non-agglomerated iron ores and concentrates 1,338,581.98 ($ Thousands). - Gold in unwrought forms non-monetary 964,923.17 ($ Thousands). - Molluscs and other aquatic invertebrates, prepa 492,878.93 ($ Thousands). - Gold in other semi-manufactured forms, non-monetary 204,325.47 ($ Thousands). - Frozen fish, nes 148,141.96 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation 1,915,982.59 ($ Thousands). - Cane or beet sugar, in solid form, nes 297,477.53 ($ Thousands). - Spelt, common wheat and meslin 261,709.16 ($ Thousands). - Pipes, line, iron or steel, smls, of a kind use 144,421.28 ($ Thousands). - Soya-bean oil (excl. crude) and fractions 131,550.65 ($ Thousands)	China $881 M, 23.32% Canada $697 M, 18.44% Spain $424 M, 11.23% Switzerland $219 M, 5.81% United Arab Emirates $206 M, 5.46%	United Arab Emirates $937 M, 18.30% Spain $824 M, 16.10% Japan $349 M, 6.81% France $342 M, 6.67% Belgium $251 M, 4.91%
Mauritius 2022	- Prepared or preserved tuna, skipjack and bonito 247,413.06 ($ Thousands). - Men's or boys' trousers, breeches, etc., of cotton 105,387.68 ($ Thousands). - Raw cane sugar, in solid form, 104,407.46 ($ Thousands). - Diamonds non-industrial nes excluding mounted 95,104.14 ($ Thousands). - Cane or beet sugar, in solid form, nes 92,256.84 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, worth 1,261,291.57 ($ Thousands). - Other coal, not agglomerated, nes 170,780.69 ($ Thousands). - Other medicaments of mixed or unmixed products, 152,759.65 ($ Thousands). - Transmission apparatus, for radiotelephone incorpo 123,327.97 ($ Thousands). Frozen skipjack or stripe-bellied bonito 116,171.72 ($ Thousands).	South Africa is worth $251 M, 13.36% France is worth $243 M, 12.94% Madagascar is worth $169 M, 9.01% The United Kingdom is worth $162 M, 8.60% The United States is worth $151 M, 8.02%	China $1,065 M, 16.10% India $646 M, 9.76% South Africa $599 M, 9.06% United Arab Emirates $595 M, 9.00% Oman $548 M, 8.27%

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Morocco 2022	- Diammonium hydrogen orthophosphate (diammonium 3,446,833.30 ($ Thousands). - Automobiles with reciprocating piston engine di 3,377,752.45 ($ Thousands). - Phosphoric acid and polyphosphoric acids 2,246,608.12 ($ Thousands). - Ammonium dihydrogen orthophosphate (monoammonium 2,049,167.70 ($ Thousands). - Ignition wiring sets&oth wiring sets of a kind 1,648,891.88 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation 9,529,540.36 ($ Thousands). - Butanes liquefied 2,165,090.77 ($ Thousands). - Spelt, common wheat and meslin 2,134,608.24 ($ Thousands). - Anhydrous ammonia 2,105,661.41 ($ Thousands). - Other coal, not agglomerated, nes 2,058,538.51 ($ Thousands).	Spain $8,279 M, 19.63% France $8,060 M, 19.11% India $2,685 M, 6.37% Italy $1,881 M, 4.46% Brazil $1,695 M, 4.02%	Spain $10,235 M, 14.10% France $7,685 M, 10.59% China $7,284 M, 10.04% United States $5,395 M, 7.43% Saudi Arabia $4,687 M, 6.46%
Mozambique 2022	- Other coal, not agglomerated, nes 2,004,858.46 ($ Thousands). - Aluminium unwrought, not alloyed 1,631,157.65 ($ Thousands). - Coke and semi-coke of coal, of lignite or of pe 847,317.47 ($ Thousands). - Electrical energy 571,027.36 ($ Thousands). - Titanium ores and concentrates 406,767.93 ($ Thousands).	- Floating docks and vessels which perform special 4,666,447.24 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation 2,271,835.05 ($ Thousands). - Fluorides of aluminium 512,525.24 ($ Thousands). - Semi-milled or wholly milled rice 315,775.37 ($ Thousands). - Crude palm oil 272,582.20 ($ Thousands).	India $1,745 M, 21.02% South Africa $1,123 M, 13.54% United Kingdom $986 M, 11.88% Korea, Rep. $501 M, 6.04% China $429 M, 5.16%	Korea, Rep. $4,695 M, 32.00% South Africa $2,290 M, 15.61% United Arab Emirates $1,466 M, 9.99% China $1,061 M, 7.23% India $842 M, 5.74%
Namibia 2022	- Diamonds non-industrial unworked or simply sawn 1,372,075.24 ($ Thousands). - Uranium ores and concentrates 813,512.75 ($ Thousands). - Gold in unwrought forms non-monetary 438,743.26 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation 386,030.28 ($ Thousands). - Diamonds non-industrial nes excluding mounted 345,716.29 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation 1,365,600.17 ($ Thousands). - Diamonds non-industrial unworked or simply sawn 544,467.03 ($ Thousands). - Copper ores and concentrates 357,437.42 ($ Thousands). - Vessels and other floating structures for break 154,013.45 ($ Thousands). - Precious metal ores and concentrates (excl. sil 144,379.62 ($ Thousands).	Botswana is worth $998 M, 17.13% South Africa is worth $855 M, 14.67% China is worth $720 M, 12.35% Unspecified worth $464 M, 7.96% Zambia is worth $297 M, 5.10%	South Africa is worth $2,794 M, 35.84% China is worth $547 M, 7.01% Unspecified worth $438 M, 5.62% Namibia is worth $362 M, 4.64% India is worth $358 M, 4.59%

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Niger 2022	- Uranium ores and concentrates 134,837.22 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation 121,960.50 ($ Thousands). - Gold in other semi-manufactured forms, non-monetary 55,629.31 ($ Thousands). - Gold in unwrought forms non-monetary 15,055.90 ($ Thousands). - Onions and shallots, fresh or chilled 12,652.75 ($ Thousands).	- Semi-milled or wholly milled rice 453,159.57 ($ Thousands). - Parts and accessories nes of heading Nos 93.01, 339,932.62 ($ Thousands). - Aircraft parts nes 240,171.78 ($ Thousands). - Helicopters of an unladen weight exceeding 2,00; 133,988.53 ($ Thousands). - Pipe, line, i or s, int/ext circ cross sect, wl 126,266.18 ($ Thousands).	France is worth $140 M, 33.18% Mali is worth $79 M, 18.74% Nigeria is worth $68 M, 16.02% United Arab Emirates is worth $38 M, 8.91% South Africa is worth $30 M, 6.98%	China is worth $904 M, 23.93% France is worth $794 M, 21.02% India worth $388 M, 10.25% Nigeria is worth $290 M, 7.67% Germany is worth $192 M, 5.08%
Nigeria 2022	- Petroleum oils and oils obtained from bituminous 49,932,928.90 ($ Thousands). - Natural gas liquefied 6,753,712.24 ($ Thousands). - Urea 1,917,537.35 ($ Thousands). - Floating or submersible drilling or production 562,456.13 ($ Thousands). - Cocoa beans, whole or broken, raw or roasted 555,393.87 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation 23,617,528.61 ($ Thousands). - Durum wheat 2,235,042.78 ($ Thousands). - Raw cane sugar, in solid form, 846,519.25 ($ Thousands). - Automobiles with diesel engine displacing more 778,026.05 ($ Thousands). - Transmission apparatus, for radiotelephone incorpo 653,302.28 ($ Thousands).	India is worth $8,013 M, 12.64% Spain is worth $7,583 M, 11.96% Netherlands is worth $6,082 M, 9.59% Indonesia is worth $4,706 M, 7.42% The United States is worth $4,408 M, 6.95%	China is worth $13,767 M, 22.69% Netherlands is worth $6,289 M, 10.37% Belgium is worth $6,266 M, 10.33% India is worth $4,810 M,7.93% The United States is worth $3,376 M, 5.57%
Rwanda 2022	- Gold in unwrought forms non-monetary, 555,740.47 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 197,695.50 ($ Thousands). - Black tea (fermented) and partly fermented tea, 101,240.46 ($ Thousands). - Coffee not roasted or decaffeinated, 92,636.20 ($ Thousands). - Other ores and concentrates, nes, 67,739.84 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 718,547.15 ($ Thousands). - Gold in unwrought forms non-monetary, 509,973.60 ($ Thousands). - Palm oil (excl. crude) and liquid fractions, 151,581.52 ($ Thousands). - Semi-milled or wholly milled rice, 136,855.09 ($ Thousands). - Cane or beet sugar, in solid form, nes, 133,059.44 ($ Thousands).	Congo, Dem. Rep. $768 M, 38.05% United Arab Emirates $590 M, 29.23% China $97 M, 4.79% India $71 M, 3.52% United Kingdom $46 M, 2.30%	China is worth $1,078 M, 21.04% Tanzania is worth $568 M, 11.08% Kenya is worth $479 M, 9.34% India is worth $476 M, 9.28% United Arab Emirates $419 M, 8.18%

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
São Tomé and Príncipe 2022	- Crude palm oil, 8,173.91 ($ Thousands). - Cocoa beans, whole or broken, raw or roasted, 8,091.32 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 4,987.20 ($ Thousands). - Coconut copra oil (excl. crude) and fractions, 262.88 ($ Thousands). - Fruits of genus Capsicum or Pimenta, dried, cru, 133.17 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation 55,727.45 ($ Thousands). - Semi-milled or wholly milled rice 7,011.62 ($ Thousands). - Generating sets, diesel or semi-diesel engines 6,777.47 ($ Thousands). - Wheat or meslin flour, 5,495.72 ($ Thousands). - Parts of electric motors, generators and generating, 3,875.38 ($ Thousands).	Netherlands $9 M, 38.63% Unspecified $5 M, 22.08% Belgium $3 M, 13.93% Portugal $2 M, 9.60% Cameroon $1 M, 3.55%	Portugal is worth $79 M, 40.33% Angola is worth $32 M, 16.05% Togo is worth $30 M, 15.43% Italy is worth $11 M, 5.37% China is worth $8 M, 4.28%
Senegal 2022	- Petroleum oils, etc., (excl. crude); preparation, 1,017,016.34 ($ Thousands). - Gold in unwrought forms non-monetary, 905,653.73 ($ Thousands). - Phosphoric acid and polyphosphoric acids, 756,170.73 ($ Thousands). - Titanium ores and concentrates, 185,577.43 ($ Thousands). - Soups and broths and preparations therefor, 165,040.17 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 2,925,397.15 ($ Thousands). - Broken rice, 459,740.54 ($ Thousands). - Petroleum oils and oils obtained from bituminous, 444,408.28 ($ Thousands). - Floating or submersible drilling or production, 333,113.77 ($ Thousands). - Other medicaments of mixed or unmixed products, 282,207.41 ($ Thousands).	Mali $1,136 M, 19.89% India $865 M, 15.16% Switzerland $664 M, 11.63% China $228 M, 4.00% Australia $225 M, 3.94%	China $1,210 M, 10.03% France $1,104 M, 9.15% India $908 M, 7.53% Belgium $757 M, 6.28% Spain $731 M, 6.06%
Seychelles 2022	- Prepared or preserved tuna, skipjack and bonito, 302,993.36 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 135,382.18 ($ Thousands). - Sailboats, with or without auxiliary motor, 44,037.93 ($ Thousands). - Frozen yellowfin tunas, 19,730.32 ($ Thousands). - Frozen tunas, nes, 17,180.61 ($ Thousands).	- Rowing boats, canoes, sculls and other pleasure, 909,621.64 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 250,606.72 ($ Thousands). - Frozen tunas, nes, 136,302.42 ($ Thousands). - Sailboats, with or without auxiliary motor, 36,104.03 ($ Thousands). - Cartons, boxes and cases of corrugated paper, 33,216.11 ($ Thousands).	France $160 M, 26.44% United Arab Emirates $149 M, 24.69% United Kingdom $83 M, 13.68% Spain $37 M, 6.07% Italy $37 M, 6.03%	Italy $541 M, 25.53% United Arab Emirates $390 M, 18.38% Netherlands $244 M, 11.49% Cayman Islands $121 M, 5.72% France $117 M, 5.53%

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Sierra Leone 2018	- Aquatic invertebrates, nes, include. flours, meals,26,647.74 ($ Thousands). - Cocoa beans, whole or broken, raw or roasted, 20,714.47 ($ Thousands). - Diesel-powered trucks with a GVW not exceeding 15,124.80 ($ Thousands). - Ash and residues containing other metals or met, 13,884.16 ($ Thousands). - Coniferous wood sawn or chipped lengthwise, sli, 12,917.84 ($ Thousands).	- Broken rice, 151,492.53 ($ Thousands). - Portland cement (excl. white), 28,922.16 ($ Thousands). - Wheat or meslin flour, 21,118.46 ($ Thousands). - Automobiles with diesel engines displacing more, 21,021.85 ($ Thousands). - Bars&rods,i/nas,hr,hd or he,cntg indent, ribs, 19,265.97 ($ Thousands).	China $37 M, w18.25% Korea, Rep. $29 M, 13.96% Netherlands $28 M, 13.55% Somalia $22 M, 10.80% Ghana $17 M,8.04%	China $198 M, 20.06% United Arab Emirates $83 M, 8.37% Belgium $74 M, 7.55% India $71 M, 7.20% United States $53 M, 5.38%
South Africa 2022	- Bituminous coal, not agglomerated, 12,185,339.18 ($ Thousands). - Rhodium unwrought or in powder form, 5,610,939.44 ($ Thousands). - Gold in other semi-manufactured forms, non-monetary, 5,264,750.96 ($ Thousands). - Agglomerated iron ores and concentrates, 4,220,019.48 ($ Thousands). - Ferrochromium containing by weight more than 4, 3,589,128.33 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 18,729,544.64 ($ Thousands). - Petroleum oils and oils obtained from bituminous, 4,397,934.67 ($ Thousands). - Transmission apparatus, for radiotelephone incorpo, 3,243,144.61 ($ Thousands). - New stamps; stamp-impressed paper; banknotes; 1,882,496.38 ($ Thousands). - Automobiles with reciprocating piston engine di, 1,580,229.43 ($ Thousands).	China $11,695 M, 9.62% United States $10,728 M, 8.82% Germany $8,835 M, 7.26% Japan $8,498 M, 6.99% United Kingdom $6,305 M, 5.18%	China $22,462 M, 20.08% India $8,334 M, 7.45% Germany $8,205 M, 7.33% United States $8,204 M, 7.33% Saudi Arabia $4,501 M, 4.02%
Sudan 2018	- Gold in unwrought forms non-monetary, 911,147.71 ($ Thousands). - Sesamum seeds, 680,106.96 ($ Thousands). - Live sheep, 466,078.15 ($ Thousands). - Petroleum oils and oils obtained from bituminous, 430,280.55 ($ Thousands). - Other live animals, nes, 217,118.48 ($ Thousands).	- Durum wheat, worth 1,688,890.96 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 1,203,798.89 ($ Thousands). - Cane or beet sugar, in solid form, nes, 616,552.46 ($ Thousands). - Wheeled tractors nes, 219,116.77 ($ Thousands). - Automobiles with reciprocating piston engine di, 193,534.79 ($ Thousands).	United Arab Emirates $994 M,27.46% China $736 M, 20.33% Saudi Arabia $588 M, 16.26% Egypt, Arab Rep. $580 M, 16.04% India $97 M, 2.69%	China $1,823 M, 17.39% Russian Federation $1,582 M, 15.09% Saudi Arabia $1,071 M, 10.22% India $874 M, 8.33% United Arab Emirates $787 M, 7.51%

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Tanzania 2022	- Gold in unwrought forms non-monetary, 2,833,711.80 ($ Thousands). - Cashew nuts, fresh or dried, 234,724.47 ($ Thousands). - Copper ores and concentrates, 193,591.61 ($ Thousands). - Semi-milled or wholly milled rice, 170,831.21 ($ Thousands). - Tobacco, partly or wholly stemmed/ stripped, 161,785.83 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 3,650,456.05 ($ Thousands). - Vaccines for human medicine, 339,702.75 ($ Thousands). - Spelt, common wheat and meslin, 333,282.95 ($ Thousands). - Other medicaments of mixed or unmixed products, 328,283.21 ($ Thousands). - Flat rild prod, i/nas, in coil, hr,=>600mm w, l, 298,790.81 ($ Thousands).	India $1,179 M, 17.27% South Africa $930 M, 13.62% United Arab Emirates $763 M, 11.18% Kenya $382 M, 5.59% Switzerland $360 M, 5.28%	China $3,945 M, 25.20% United Arab Emirates $2,492 M, 15.92% India is worth $1,961 M, 12.52% Saudi Arabia $610 M, 3.90% South Africa $549 M, 3.51%
Togo 2022	- Unground natural calcium phosphates, aluminium, 299,789.84 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 93,601.44 ($ Thousands). - Sacks and bags (incl. cones) of polymers of eth, 90,249.90 ($ Thousands). - Soya beans, 76,448.31 ($ Thousands). - Beauty, make-up, skincare (incl. suntan), nes, 75,623.61 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 149,391.79 ($ Thousands). - Other medicaments of mixed or unmixed products, 96,352.73 ($ Thousands). - Petroleum bitumen, 81,463.56 ($ Thousands). - Motorcycles with reciprocating piston engine di, 79,574.05 ($ Thousands). - Electrical energy, 71,774.90 ($ Thousands).	India $229 M, 16.97% Burkina Faso $168 M, 12.45% Benin $127 M, 9.41% Cote d'Ivoire $114 M, 8.43% Mali $101 M,7.48%	China $552 M, 19.76% France $246 M, 8.83% India $171 M, 6.14% Nigeria $121 M, 4.33% Ghana $113 M, 4.06%
Tunisia 2022	- Electric conductors, for a voltage not exceeding 1,059,060.87 ($ Thousands). - Petroleum oils and oils obtained from bituminous, 844,763.46 ($ Thousands). - Virgin olive oil and fractions, 764,512.49 ($ Thousands). - Ignition wiring sets&oth wiring sets of a kind, 667,907.46 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation, 614,489.02 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 2,341,070.18 ($ Thousands). - Petroleum gases and other gaseous hydrocarbons, 1,151,321.79 ($ Thousands). - Petroleum oils and oils obtained from bituminous, 788,160.22 ($ Thousands). - Spelt, common wheat and meslin, 539,724.84 ($ Thousands). - Butanes, liquefied, 442,388.95 ($ Thousands)	France $4,128 M, 22.26% Italy $3,119 M, 16.82% Germany $2,396 M, 12.92% Spain $832 M, 4.48% Unspecified $818 M, 4.41%	Italy is worth $3,896 M, 14.61% China is worth $2,792 M, 10.47% France is worth $2,765 M, 10.37% Turkey worth $1,634 M, 6.13% Algeria is worth $1,588 M, 5.95%

Countries	Top 5 Product exports (HS 6-digit level) in Billions of $	Top 5 Products imports (HS 6-digit level) in Billion of $	Top 5 Export Partners (2017) Billion $	Top 5 Import Partners (2017) Billion $
Uganda 2021	- Gold in other semi-manufactured forms, non-monetary, 1,028,061.15 ($ Thousands). - Coffee not roasted or decaffeinated, 713,153.51 ($ Thousands). - Cocoa beans, whole or broken, raw or roasted, 105,843.97 ($ Thousands). - Petroleum oils, etc., (excl. crude); preparation 99,430.80 ($ Thousands). - Cane or beet sugar, in solid form, nes, 85,765.37 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 1,236,043.46 ($ Thousands). - Gold in other semi-manufactured forms, non-monetary, 844,401.27 ($ Thousands). - Other medicaments of mixed or unmixed products, 268,576.54 ($ Thousands). - Crude palm oil, 259,825.75 ($ Thousands). - UGold in unwrought forms non-monetary, 250,190.01 ($ Thousands).	United Arab Emirates $1,063 M, 26.81% Kenya $526 M, 13.25% South Sudan $484 M, 12.20% Congo, Dem. Rep. $339 M, 8.56% Italy $210 M,5.30%	China $1,652 M, 18.19% India $1,051 M, 11.57% Tanzania $821 M, 9.03% United Arab Emirates is worth $811 M,8.92% Kenya $770 M,8.47%
Zambia 2022	- Copper unrefined, copper anodes for electrolysis, 6,131,039.30 ($ Thousands). - Copper cathodes and sections of cathodes unwrou, 1,715,965.28 ($ Thousands). - Crude or unrefined sulphur, 302,313.29 ($ Thousands). - Electrical energy, 300,120.57 ($ Thousands). - Ferro-silicomanganese, 171,640.08 ($ Thousands).	- Petroleum oils, etc., (excl. crude); preparation, 479,637.02 ($ Thousands). - Crude or unrefined sulphur, 390,269.20 ($ Thousands). - Copper ores and concentrates, 374,207.95 ($ Thousands). - Cobalt oxides and hydroxides; commercial cobalt, 250,973.97 ($ Thousands). - Other medicaments of mixed or unmixed products, 227,842.09 ($ Thousands).	Switzerland $4,487 M, 38.54% China $2,407 M, 20.67% Congo, Dem. Rep. $1,589 M, 13.64% Singapore $1,228 M, 10.54% South Africa $268 M, 2.30%	South Africa is worth $2,705 M, 30.04% China is worth $1,387 M, 15.41% United Arab Emirates is worth $684 M, 7.60% Congo, Dem. Rep. worth $658 M, 7.30% India is worth $589 M, 6.54%
Zimbabwe	- Gold in other semi-manufactured. forms, non-monetary, $1.99B - Nickel ores and concentrates $1.10B - Nickel mattes $1,024B - Tobacco, partly or wholly stemmed/ stripped 0$. 91B - Ferrochromium containing by weight more than $4.36B	- Petroleum oils, etc., (excl. crude); preparation $1.33B - Crude soya-bean oil, 289,499.10 ($ Thousands). - Electrical energy, 207,794.12 ($ Thousands). - Broken rice, 145,929.87 ($ Thousands). - Other medicaments of mixed or unmixed products, 128,974.98 ($ Thousands).	South Africa $2,756 M, 41.84% United Arab Emirates $2,126 M, 32.28% China $583 M, 8.85% Belgium $215M 3.26% Mozambique $190M 2.89%	South Africa $3,480 M, 40.4% China $1,192 M, 13.86% Singapore $1,170 M, 13.60% Mozambique $335 M, 3.89% Mauritius $315 M, 3.66%

3.2.4 The status of STI capabilities

Measuring the capabilities in Science, Technology and Innovation (STI) at the national level is challenging, as it requires capturing all factors that contribute to innovation. The Global Innovation Index (2023), published by WIPO, serves as a tool for this purpose. It employs various indices, categorised as input and output, with additional sub-indices within them. The main indices are:

Inputs

- **Institutions: This section includes the institutional environment, regulatory framework for Science, Technology and Innovation (STI), as well as the business environment.**
- **Human capital and research**: Expenditure on education, Pupil-teacher ratio, secondary, Tertiary enrolment, Graduates in science and engineering, Researchers- FTE, Gross expenditure on R&D.
- **Infrastructure** ICT access, government online services, electricity outputs, general infrastructure and ecological sustainability.
- **Market Sophistication** credit, investment, trade, diversification and market scale.
- **Business sophistication** among sub-indices includes Knowledge-intensive employment, Firms offering formal training, GERD performed by business, GERD financed by business and University-industry R&D collaboration.

Output

- **Knowledge and technology outputs**, among others – divided into outputs and impacts are Outputs – Patents by origin, Scientific and technical articles and impacts – High-tech manufacturing, Labour productivity growth, Production and export complexity.
- **Creative outputs**: Intangible asset intensity, Trademarks by origin, Cultural and creative services exports, entertainment and media market.

WIPO ranks 132 countries of the world according to their scores in these indicators (**input**). Tables 3.3 and 3.4 include the top ten countries worldwide and the top ten African countries. From the two tables, one can depict how far Africa is from the top leaders in innovation capabilities. The tables include 4 of the 7 broad indicators or pillars.

Table 3.3 Top 10 global leaders in STI capabilities

Country & Position		Institutions	Human capital and research	Infrastructure	Market sophistication	Business sophistication
Switzerland	**1**	2	6	4	7	5
Sweden	**2**	18	3	2	10	1
United States	**3**	16	12	25	1	2
United Kingdom	**4**	24	8	6	3	13
Singapore	**5**	1	2	8	6	3
Finland	**6**	3	5	1	12	4
Netherlands Kingdom of the	**7**	6	13	14	15	8
German	**8**	22	4	23	14	16
Denmark	**9**	5	9	3	21	12
Republic of Korea	**10**	32	1	11	23	9

Table 3.4 Top 10 African countries in global innovation

Country	Position	Institutions	Human capital and research	Infrastructure	Market sophistication	Business sophistication
Mauritius	**57**	26	64	74	24	91
South Africa	**59**	88	84	68	45	61
Morocco	**70**	83	86	94	80	107
Tunisia	**79**	107	46	89	98	119
Botswana	**85**	37	73	85	70	56
Egypt	**86**	103	95	90	88	100
Cabo Verde	**91**	44	97	64	96	65
Senegal	**93**	59	107	98	81	122
Namibia	**96**	50	76	100	84	99
Ghana	**99**	93	105	105	117	83

3.2.5 Conclusion and Recommendations

The conclusion is that the analysis of export and import dynamics across countries in the continent is based on the potential for innovation and value addition for competitive advantage status. This has shown a few things such as disparities across countries justified by recorded export-import traded volumes and import/export networks across countries and within the regional trading blocks. Further, African countries are prominently connected to key global economies, implying that there are opportunities for enhanced learning and capabilities strengthening by drawing from the best fit and best practices. In terms of trade and technology intensity, African countries' technology sophistication (% of high-tech in exports) against global statistics is significantly low. This is worrying because it creates an imbalance at the global trade level.

It is recommended to promote discussions at the regional level, focusing on institutions and policies that are required to build localised structure-based STI fit for purpose capabilities towards more technology and innovation-intensive economic sectors.

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3.3 THE ROLE OF THINK TANKS IN ASSESSING THE IMPACT OF AFRICA'S DEMOGRAPHIC DIVIDEND ON INCOMES AND CARBON EMISSIONS

Think tanks are crucial in analysing population data, economic trends and social policies. However, their potential to inform policy development through their association with policymakers is often underutilised. The AUDA-NEPAD Policy Bridge Tank Programme helps to bridge this gap by linking the analysis provided by its members, which consists of the key African think tanks, to African policymakers at the national, regional and continental levels.

Policy Bridge Tank helps to close the gap between the supply of evidence-based research and recommendations from African-based institutions and the demand amongst African policymakers to jointly pursue the **Agenda 2063** long-term vision of an integrated, prosperous and peaceful Africa driven by its own citizens, representing a dynamic force in the international arena.

Africa is at a crossroads. On the one hand, the continent is on the brink of significant economic growth, much of that a function of its rapidly growing and youthful population. The numbers are well known. Currently, Africa constitutes 18% of the world's population. At the termination of Agenda 2063, that portion will be 28% and continue to increase rapidly to the extent that one in every three people will be African at the end of the century. However, Africa's growing share of working-age men and women as a portion of its total population is more important than absolute numbers.

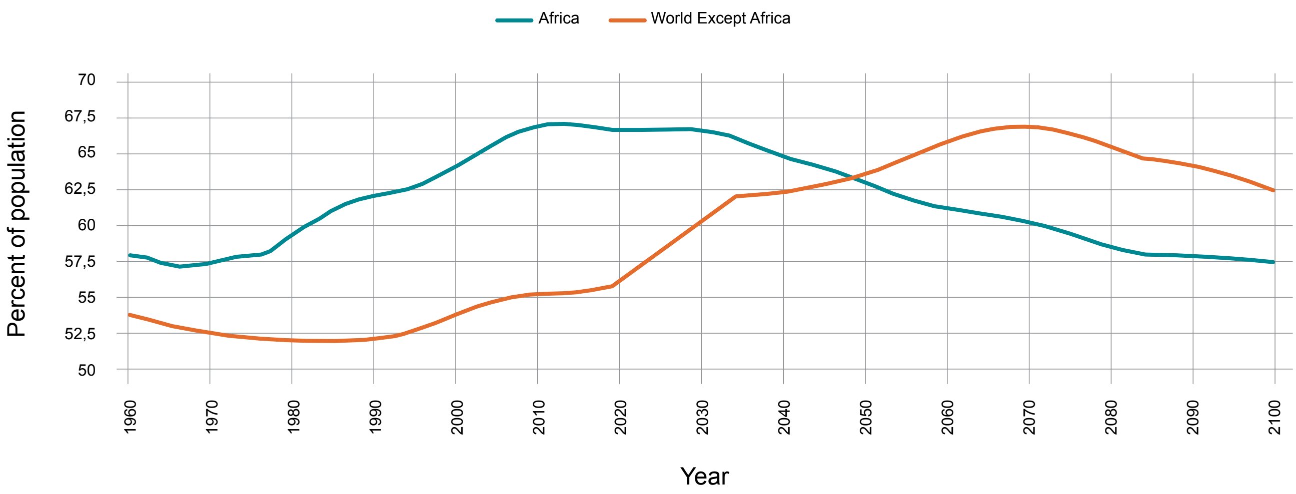
The larger the percentage of working-age persons as a portion of the total population, the more rapidly countries tend to grow economically, particularly at lower levels of development.

Currently, 57% of Africa's population is of working age and this percentage is on the rise. In contrast, the rest of the world has a higher proportion of working-age individuals at 67%, but this rate is declining. If current trends continue, Africa will reach a point around 2048 where the working-age population will surpass that of the rest of the world. By that time, the percentage of working-age individuals in Africa will continue to grow, peaking at approximately 67% two decades later. In contrast, the working-age share in the rest of the world is expected to fall to around 60% and continue to decline.

Whilst many regions such as Europe, North America, countries like Russia, Iran, Japan, the Asian Tigers and others are already struggling with aging populations and labour shortages, Africa will have an abundance of working age people – more than it can absorb, meaning that population movements on the continent and migration pressures elsewhere will inevitably increase.

Should Africans invest in education, improve healthcare and provide jobs, Africa's growing demographic window of opportunity could translate into a dividend with subsequent rapid economic growth and poverty reduction not dissimilar to that experienced by the Asian Tigers and China in recent history.

Figure 3.14 Population ages 15-64 history and forecast% of population

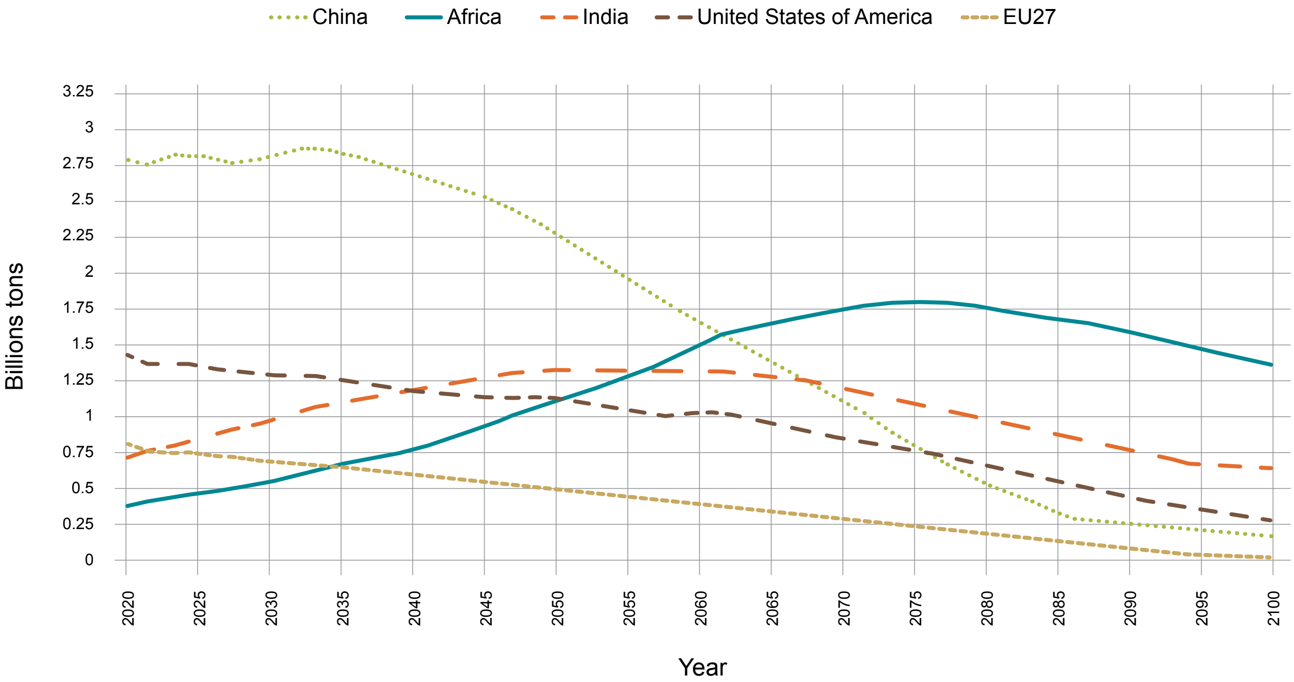


Source: Frederick S. Pardee Institute for International Futures. International Futures at Pardee Institute, University of Denver | https://korbel.du.edu/pardee/international-futures-platform

Therefore, Africa's youthful demographics represent an unparalleled potential for the future but pose substantial challenges regarding resources, education, healthcare and employment opportunities.

With opportunities come risks. Most important among these is the extent to which Africa's rapidly growing population could contribute significantly to carbon emissions and global warming without early action to place the continent on a low-carbon growth path. Africa suffers from extreme energy poverty. Given the strong relationship between population growth, economic growth and carbon emissions, Africa will likely emerge as the largest source of carbon emissions from fossil fuels globally unless it changes its growing addiction to coal, oil and gas. On the current trajectory, Africa's carbon emissions from fossil fuels will overtake those of the European Union in 2034, the US in 2050, India in 2056 and China in 2063. Clearly, the continent must invest in alternative clean energy sources, including wind, solar and nuclear as early as possible if it is to avoid massive self-inflicted harm to itself and the rest of the world.

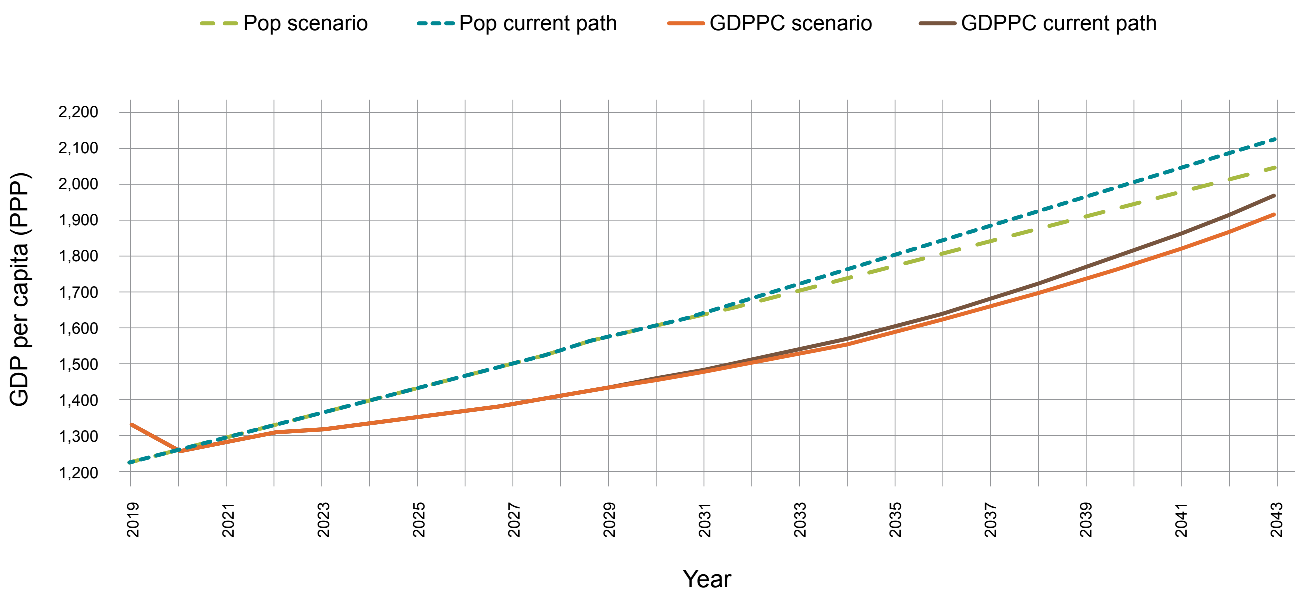
Figure 3.15 Carbon emissions from fossil fuels – billions of carbon



Source: Frederick S. Pardee Institute for International Futures. International Futures at Pardee Institute, University of Denver | https://korbel.du.edu/pardee/international-futures-platform

Modern contraceptives, better healthcare, female empowerment, education and related measures can play an essential role in advancing income growth since reductions in total fertility rates increase the ratio of working-age persons to dependents and intensify a potential demographic dividend with positive effects on average income. As part of our work on African Futures at the Institute for Security Studies, we have modelled an ambitious scenario on demographics and health that illustrates the relationship. Should Africans roll out availability of modern contraceptives and invest in better healthcare and female empowerment, the continent could have a 2043 population that is 74-million smaller but GDP per capita that is USD199 higher. A population that is 2.9% smaller can lead to a 3.5% increase in GDP per capita. This is because there are more working-age individuals (those aged 15 to 64) relative to the number of dependents, such as children and the elderly. Additionally, a smaller population results in lower carbon emissions, benefiting both Africa and the global environment.

Figure 3.16 Demographics and income



Source: Frederick S. Pardee Institute for International Futures. International Futures at Pardee Institute, University of Denver | https://korbel.du.edu/pardee/international-futures-platform

The work of the African Futures team highlights several complexities regarding the continent's economic landscape. Our forecast, which examines the impact of eight different sectoral scenarios for each African country, indicates that the full implementation of the African Continental Free Trade Area (AfCFTA) would contribute more to poverty reduction and average income increases than any other sectoral intervention. In the long run, it outperforms both an agricultural revolution and a transition to manufacturing, as it facilitates advancements in both areas.

Africa will not achieve significant development without regional trade integration, as our markets are too small. Additionally, we cannot improve our position in the export value chain, attract foreign investment or become integrated into global value chains without it. The necessity and motivation for the AfCFTA are therefore clear, particularly given the pressing need to create employment opportunities for the continent's growing youth population. Currently, individuals aged 15 to 29 represent 45% of Africa's adult population. This figure is projected to gradually decline to 39% by 2043, still leaving a substantial cohort that could create political instability if adequate opportunities are not provided.

The successful implementation of the AfCFTA offers significant growth opportunities. It has the potential to greatly benefit the well-being, rights and future of Africa's young population while also advancing the Sustainable Development Goals and Agenda 2063 ambitions. Conversely, the trajectory of this youthful demographic will play a role in determining the effectiveness and impact of the AfCFTA.

Given the symbiotic relationship between the AfCFTA and the continent's youth, it is crucial to examine, discuss and strategise on how trade agreements like the AfCFTA can be shaped to maximise benefits for the younger generation while mitigating potential risks. This becomes even more critical considering that Africa's Human Capital Index score trails behind the global average, indicating an urgent need for policies that catalyse human capital development.

As part of its mission to bridge the policy gap between African governments and think-tanks, AUDA-NEPAD has partnered with the African Futures & Innovation programme at the Institute for Security Studies (AFI-ISS), to strengthen and align development forecasting and analytic capabilities in AUDA-NEPAD, relevant Member States and regional institutions. The partnership aims to generate context-specific foresight and knowledge products as direct inputs to an evidence-based determination of appropriate development policy and investment choices. These inputs can help shape policies that will influence the future of our societies.

This joint chapter by AUDA-NEPAD Policy Bridge Tank and AFI-ISS demonstrates the use of think tanks' knowledge content at regional, national and continental levels. It highlights think tanks' crucial role in assessing the demographic dividend and its relationship to growth and carbon emissions.

Africa's young population can be an asset for AfCFTA and the Bridge Tank is committed to exploring catalytic investments that will drive AfCFTA's success while maximising its positive impact on Africa's young population.

Foresight analysis is an important tool for anticipating future trends and their potential impacts. It can help identify potential future scenarios for Africa's youth concerning trade agreements like AfCFTA. It can provide insights into how different factors such as demographic trends, economic developments, technological advancements and policy changes might interact to shape future outcomes. By incorporating foresight analysis into our thinking and planning, we aim to ensure that our strategies are robust and flexible enough to adapt to alternative futures.

Think tanks can help policymakers understand the implications of demographic changes and develop strategies to harness this potential for economic growth. By doing so, we aim to inform policymakers, stakeholders and the broader public, advocating for trade reforms that are inclusive, beneficial and cognisant of the rights and needs of Africa's young generation.

3.4 INDUSTRIALISING AFRICA THROUGH EDUCATION AND EMERGING TECHNOLOGIES

3.4.1 Background

Education is a basic human right and the sharing of knowledge effectively continues to be a major determinant of success in Africa. Africa stands at a pivotal moment in its development trajectory, with a growing recognition of the role that education, innovation and emerging technologies play in driving industrialisation across the continent. One of the goals of the African Union (AU) Agenda 2063 is to establish knowledge societies in Africa driven by skilled human capital. To this end, education is recognised as cross-cutting and very important in delivering the necessary human capital to contribute to the realisation of AU Agenda 2063 aspirations, goals and priority areas of industrialisation.

The AU Agenda 2063 recognises science, technology and innovation (STI) as multi-functional tools and enablers for achieving continental development goals. The Agenda 2063, Science, Technology and Innovation Strategy for Africa (STISA-2024), Continental Education Strategy for Africa (CESA 2025) and the Digital Transformation Strategy for Africa (2030) provide a framework for strengthening formal, non-formal and informal education as well as harnessing of science, technology and innovation for enhancing industrialisation and socio-economic development in Africa.

The AU has declared education a priority for 2024, adopting the theme "Educate an African fit for the 21st Century – Building resilient education systems for increased access to inclusive, lifelong, quality and relevant learning in Africa." Through this theme, the AU acknowledges education as both a fundamental human right and a crucial driver for the continent's progress. Through the propagation of the importance of education and the strengthening of educational systems, the AU aims to achieve sustainable benefits such as an educated and technologically skilled workforce, enhanced social cohesion, increased adoption of innovation and emerging technologies, resilient communities and boosted investment in manufacturing and industries.

Education serves as a transformative force, fostering economic development, societal progress and individual empowerment. In Africa, the significance of education to industrialisation cannot be overstated. To this end, African governments and private sector entities have played a critical role in nurturing innovation and emerging technology and strengthening their education ecosystems, particularly following the Covid-19 pandemic. Case studies from across the continent show that countries are slowly harnessing the power of education and cutting-edge technologies to address a wide range of challenges in the industrial sector. However, despite these efforts, wide gaps still exist in teaching and learning as well as curriculum development, which tends to result in a misfit between graduates and the skills required by the labour force. Hence, improving industrialisation in Africa calls for pragmatic and feasible approaches that interrogate past strategies for the educational sector and the challenges that remain and adopt new fit-for-purpose strategies.

3.4.2 Innovative Education and the Future of Work

It has been determined that successful transition to a knowledge-based economy often includes four elements: long-term investment in education, the development of innovation capability, the modernisation of the information infrastructure and the creation of a conducive economic environment. Recognising the pivotal role of education in industrialisation, African nations have made significant strides in expanding access to quality education for all. From primary schools to universities, efforts have been made to equip students with the skills and knowledge needed to thrive in an increasingly digital world (Chebib, K, 2020). Initiatives such as vocational training programmes and lifelong learning opportunities have been instrumental in empowering individuals to adapt to the rapidly evolving technological landscape. Africa has made meaningful progress in education over the past 60 years, with more girls in school and more students in tertiary education than ever before. School completion rates have increased from 2000 to 2022 at all levels: from 52% to 69% in primary, 35% to 50% in lower secondary and 23% to 33% in upper secondary (Shabir A. et al, 2023). As African countries work towards industrialisation, investing in education and leveraging emerging technologies in teaching and learning have become critical strategies for sustainable economic growth and development.

There is now compelling evidence about the disruptive capability of technology transformation in facilitating teaching and learning. Technology has the potential to revolutionise education by breaking down traditional barriers to learning and providing access to quality education resources (Van Manen, H. et al, 2021). With the proliferation of mobile devices and internet connectivity across Africa, digital learning platforms, online courses and educational apps have become increasingly accessible to students of all ages and backgrounds. These tools offer interactive learning experiences, personalised instruction and opportunities for collaboration, enabling students to develop critical thinking, problem-solving and digital literacy skills essential for success in the modern economy.

African countries need innovative education and capacity-building mechanisms to develop sustainability competencies. For the informal sector in Africa, it is crucial to strengthen the curricula of Technical, Entrepreneurial and Vocational Education and Training (TVET) by focusing on skills relevant to the emerging needs in Science, Technology and Innovation (STI). This targeted approach could have significant positive effects on work within the informal sector. Additionally, there is a need for a solution-oriented approach to education at the local, national and transnational levels.

Education and training in innovation and emerging technologies will build the capacities of African countries to create innovative and industrialised economies. This is a necessary response to gaps in knowledge innovation in business models as this can be transformative and is critical to businesses of the future. These are often underpinned by emerging technologies in IT, big data and the Internet of Things and are necessary for the realisation of the potential presented by emerging technologies. The Covid-19 pandemic and its consequential impact have created a “new normal” culture with increased reliance on innovation and emerging technologies and has exposed the unpreparedness of many educational institutions in Africa to migrate online. This realisation calls for educational reforms, which should embrace three central competencies, such as “critical thinking”, “normative dialogue” and “transformative leadership”.

Critical thinking is indispensable as a tool to synthesise problems and their solutions repeatedly (Shabir Ahmad et al, 2023). Normative dialogue is important as the ability to understand and work with diverse opinions and ideas about values, while transformative leadership is the capacity to implement solutions in diverse stakeholder contexts. Integrating interdisciplinary approaches and project-based learning can help students develop critical thinking, creativity and collaboration skills essential for success in the digital era. Hence, going forward, the educational systems of African countries must be recalibrated to accommodate appropriate skills in the education curriculum to meet the demands of the workplace.

3.4.3 Enhancing STEM Education Towards Industrialisation

Over the past two decades, the number of young graduates in Africa entering the workforce has significantly increased. However, the proportion of youth qualified to fill positions in Science, Technology, Engineering and Mathematics (STEM) fields, such as manufacturing, has remained stagnant. The enhancement of STEM knowledge, skills and capacity in African countries faces several barriers and misconceptions. These include a generic curriculum, a shortage of qualified STEM teachers, insufficient professional development opportunities for educators, inadequate policies, limited research, poor access to technology and challenges in attracting and retaining students in STEM courses and careers (Chebib, K. 2020). Another component of the problem is the lack of inclusiveness. Gender stereotypes are considered as a major driver of these disparities. Many African countries have moved from a knowledge-based curriculum to a Competency-Based Curriculum with more practical application and experimentation (Van Manen, H. et al, 2021). However, despite these efforts, there is a disconnect between STEM in the curricula and the demands of the labour market.

Africa can foster a generation of young innovators and problem solvers by promoting STEM education from an early age. This will prepare them to contribute effectively to the continent's industrialisation. As automation and artificial intelligence reshape the job market, individuals with a combination of technical expertise and human-centric skills will be in high demand. By fostering a holistic educational experience that nurtures both hard and soft skills, Africa can create a workforce that is not only adept at leveraging technologies but also empathetic and capable of driving positive change in society and contributing to industrialisation.

3.4.4 Skills for Industrialisation Within 4IR

As stated by Klaus Schwab, founder and executive chairman of the World Economic Forum, "The First Industrial Revolution used water and steam power to mechanise production. The Second used electric power to create mass production. The Third used electronics and information technology to automate production. Now, a Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterised by a fusion of technologies that is blurring the lines between the physical, digital and biological spheres" (Van Manen, H. et al, 2021). Hence, for Africa to benefit from the 4IR, it is imperative for countries to optimise the utilisation of emerging technologies for all development sectors.

Currently, African countries face a significant digital divide in workforce preparedness for industrialisation due to the lack of infrastructure, low skill levels and high capital costs that hamper automation. In addition, they also benefit less from digitalisation. If this digital divide is not adequately closed, African countries may face detrimental effects from a growing digitalised global economy in terms of job losses (Bryant, Jake, et al, 2020). To develop a strong industrialisation sector and create a prosperous and sustainable future for Africa, governments should prioritise the skills required in high-growth job sectors, particularly concerning the Fourth Industrial Revolution (4IR). This includes technologies such as robotics, artificial intelligence, 3D printing, additive manufacturing and the Internet of Things.

Innovation utilisation and the effective harnessing of emerging technologies are important in addressing concerns of job losses linked to a lack of skills. Currently, there is limited readiness in leveraging these technologies. Hence, a critical factor is the need for capacity building and strengthening for relevant stakeholders across African countries. Beyond formal education and in responding to changing labour market conditions, capacity-building and strengthening programmes should be undertaken by countries. These should inculcate problem-solving abilities and critical thinking, contextualised to address Africa's industrialisation challenges.

Basic digital skills will be essential in future labour markets. Therefore, universal access to these skills is crucial for African countries to prevent a digital divide that excludes segments of the population from formal employment. Basic digital skills should go beyond user and information skills to include analytical skills like coding (Shabir Ahmad et al, 2023). With the right investments and policies in place, African countries can harness the transformative potential of education and emerging technologies to build a dynamic industrialisation sector and ultimately a prosperous and sustainable future for Africa.

3.4.5 Harnessing Africa's Youth Dividend

Africa is home to a youthful and dynamic population that holds tremendous potential to drive industrialisation through innovation and the adoption of emerging technologies. With over 60% of its population under the age of 25, Africa's youth represent a vast pool of talent, creativity and entrepreneurial spirit that can be leveraged to propel the continent's industrial growth and economic transformation (Mutiso, Rose and Katie Hill, 2020). The role of Africa's young population in harnessing innovation and emerging technologies for industrialisation is multifaceted. Across the continent, young Africans are leveraging their education and creativity to develop innovative solutions to local and global challenges, bringing fresh perspectives and a willingness to challenge the status quo.

With the rapid expansion of digital connectivity across the continent, Africa's young people are embracing technology as a tool for economic opportunity. From coding bootcamps and hackathons to innovation hubs and maker spaces, young people are collaborating and co-creating solutions to address local challenges and drive sustainable development. From mobile banking platforms to renewable energy technologies, young African innovators are making significant contributions to industrialisation. Africa's youth are at the forefront of the continent's burgeoning startup ecosystem. From Silicon Savannah in Kenya to Yabacon Valley in Nigeria, young entrepreneurs are launching innovative startups that are disrupting traditional industries, creating jobs and driving economic growth (Mueller-Kaler, J. 2020). Through youth-led advocacy campaigns and engagement with policymakers, young people are shaping the policy agenda and driving reforms to create an enabling environment for industrialisation and economic growth.

Another population segment that is important to the discourse on industrialisation is the informal sector. In most African countries, over 65% of workers are in the informal sector, either in traditional agriculture or in urban informal economic activities. The employment situation has also been unfavourable for women, almost 70% of whom are employed informally (Shabir Ahmad, Chebib, K., 2020).

In recent years, African countries have experienced rapid economic growth; however, this has not addressed the optimal utilisation of the youth in Africa for industrial development. The youth in Africa still have a higher share of unemployment than the adults. Increasingly, the face of the unemployed or informal sector worker in Africa is no longer only the uneducated man or woman, but also a secondary or tertiary school graduate. Hence, there is an urgent need for governments and the private sector to support young people engaged in the informal sector. With the right education and skills, coupled with well-defined national development strategies and employment policies, Africa's large and fast-growing youth population could be harnessed as an important component of the workforce needed for industrialisation in Africa.

3.4.6 Recommendations for Governments and Relevant Stakeholders

i. **Invest in education and skills development:** prioritise investments in education and skills development programmes to equip the African workforce with the necessary technical and entrepreneurial skills needed to thrive in the digital economy

ii. **Invest in improving education data and education management information systems:** to produce quality data to support evidence-based programming, inform policy and allow a country's progress to be monitored against national, regional and continental goals

iii. **Curriculum reform:** update and modernise educational curricula to incorporate emerging technologies, 21st-century skills and industry-relevant content

iv. **Education, skill development and capacity building:** collaborate with African countries to initiate educational ventures to nurture a workforce equipped for GVCs. This should encompass specialised training programmes, vocational education and higher education programmes tailored for pertinent industries; facilitate capacity building in African countries to equip them with the essential skills and knowledge needed for industrialisation

v. **Promotion of digitalisation and eco-friendly technologies:** African countries should fortify their information and communications technology (ICT) frameworks, ensure affordable and reliable high-speed internet and power solutions; African governments should nurture human resources in the digital realm

vi. **Prioritise digital connectivity for learning and skills development:** Ministries of Education to develop strategic partnerships with telecommunications companies and internet providers (to bring down the cost of airtime, mobile data and broadband services)

vii. **Prioritise teacher training, including digital skills for pedagogy:** prioritise redesigning of teacher development programmes at all levels, including digital and pedagogical skills for learner-centred, inclusive quality education

viii. **Research and development:** invest in research and development initiatives that focus on advancing technology-enhanced teaching and learning methodologies

ix. **Science policy** for knowledge acquisition will have to be an important priority moving forward. It will be up to policymakers and science literacy advocates to reinforce science and technology teaching and resources at all levels of education

x. **Public-private partnerships:** foster collaboration between educational institutions, government agencies and private sector stakeholders to co-create and co-deliver technology-centred education programmes

Additional recommendations for smart manufacturing and industrial skills:

xi. **Integrate smart manufacturing into curricula:** incorporate Industry 4.0 themes – such as robotics, automation, artificial intelligence, additive manufacturing and industrial IoT – into vocational and higher education to prepare graduates for the future of work

xii. **Establish smart factory demonstrators and training labs:** governments, universities and industry should collaborate to create pilot smart factories and digital labs that provide hands-on training and serve as platforms for experimentation, innovation and SME support

xiii. **Promote specialised workforce development for advanced industries:** develop regional centres of excellence for advanced manufacturing and industrial digital skills, ensuring alignment with priority sectors such as agro-processing, mining beneficiation, renewable energy and logistics

xiv. **Encourage industry-academia co-creation:** facilitate joint programmes between educational institutions and industries to co-design learning modules, apprenticeships and dual-training systems tailored to smart manufacturing needs

xv. **Support lifelong learning for industrial workers:** Eestablish continuous professional development pathways, including reskilling and upskilling initiatives, to help Africa's workforce adapt to rapid technological changes in manufacturing and industrial operations

3.4.7 Conclusion

African countries have made strides in enhancing their educational systems. However, challenges such as limited access and adoption of education-related emerging technologies and a lack of relevant skills, hinder countries from utilising opportunities for industrialisation. Innate human capabilities such as critical thinking and technological skills become important, implying that formal and nonformal education, vocational training and capacity building are critical in building quality human capital for industrialisation. Consequently, educational institutions in Africa must rethink the future of education and work and take practical steps towards integrating emerging technologies and strengthening the educational systems to ensure that Africa's workforce, especially the youth, contributes effectively to industrialisation.

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CHAPTER 4
ACCELERATING INDUSTRIALISATION IN AFRICA THROUGH STI POLICIES

4.1 THE ROLE OF POLICY RESEARCH IN INNOVATION AND INDUSTRIALISATION

4.1.1 Background

There is now a consensus that innovation is a cornerstone of the social and economic development of countries; and recently, for addressing emerging issues such as climate change and inequalities within and between nations. This has prompted countries to put efforts into building the innovation capabilities of their nations through appropriate policies. Innovation policies can play a crucial role in improving the conditions for innovation, identifying and addressing bottlenecks that impair the ability of countries to innovate and improve productivity.

Innovation policy simply means public intervention to support the generation and diffusion of innovation. Like other forms of public policy, innovation policy is implemented through policy instruments – defined as a set of techniques by which state authorities use their power in an attempt to ensure support and effect or prevent social change (Borras and Edquist, 2013). Innovation being a systemic, dynamic and context-specific concept, Borras and Edquist (2013) argue that innovation policy instruments must be designed, redesigned and adapted through time to the specific and context-bound problems in an innovation system. Based on such understanding and use of the concept of innovation as a systemic endeavour, some countries have moved up the innovation capability ladder and caught up with rich countries in social and economic development. The Asian tigers are a case in point, whereby, the involved countries transformed their economies by improving the technological and innovation performance of their industries through purposeful science and technology policies that are closely coordinated with the industrial policy (Winston, 2006).

As for Africa – as indicated in this volume (2.2) on Country GDPs, Export and Import profiles – many countries remain overly dependent on natural resource exports and therefore questions on how to diversify economies through the development of technological and innovative capabilities; how to foster innovation and how to develop a learning economy, remain central to the development processes. At the same time, new questions that relate to how innovation is – or is not – providing equality or equity of opportunity at individual, community, sub national, national and international levels, are becoming increasingly important. Along with all these, issues regarding environmental sustainability are also increasingly becoming a major challenge to the survival of humankind – making innovation policy for African economies even more complex, requiring wellgrounded expertise. To be effective, innovation policies need to be evidence-informed, with evidence produced through high-quality research that is informed by context-based theoretical propositions. Hitherto, existing innovation theories used in the African context are based on theoretical foundations that have been informed by empirical evidence from more developed countries. This implies that they are inappropriate for wholesale use in an African context, largely requiring adaptation through empirical evidence generated from this context. Such research could be on the identification of problems/issues and causes of the problem for a particular issue or sector, such as the manufacturing sector; or filling the knowledge gaps in the strategies declared to achieve a pre-determined objective, such as increasing the number of engineers in the labour market. Other issues could be related to increasing local content in the pharmaceutical or energy sector, addressing environmental consequences and inequality in social and economic systems or just strengthening the national, sectoral and local innovation system to achieve a pre-determined innovation policy objective.

More generally, a context-based study of the innovation system is key to understanding the way science, technology, innovation (STI) and society interact to enhance the knowledge base available for policy makers and practitioners as they make decisions concerning future development paths in African countries and implement key strategies such as

AU Agenda 2063. Innovation system is defined in the writing of renowned innovation systems scholars such as Freeman (1987), Lundvall (1988, 1992), Nelson (1993), Edquist (1997) – among others – as a system of actors and interactive learning among these actors that together bring forth innovation at the national, global and local levels. Most cited system actors in these literature sources include firms and farms (the productive sector that is at the centre of the system), higher learning institutions that produce knowledge for innovation, firms' suppliers, buyers and competitors, financial institutions and policy organisations.

The kind of research that is good for innovation policy cannot be carried out by just any researcher but requires specialised expertise in a specialised field of social sciences. The field has been given different names by different universities, including STI policy; science policy; science and technology policy; innovation studies/innovation and development (I&D). This later terminology has been adopted for this innovation outlook to align with the innovation and industrialisation theme of the Chapter. While poor countries such as those in Africa require innovation policy more than developed countries, where usually markets allocate resources for innovation, Africa is seriously lacking in such expertise. In the sections that follow, an attempt will be made to paint a rough picture of the status of competence and capabilities in this specialised field, looking at research capacity more generally which includes human resources, funding, publications and university curricular and other capacity building efforts.

4.1.2 Status of Innovation Policy Research Capacity in Africa

Innovation and development (I&D) and related policy research is an emerging field, especially in Africa[5]. Innovation Studies as a modern academic field started emerging in the 1950s and has since then been used worldwide to support national and international strategies for development.

Much of the interrogation related to innovation and development is understood in the context of the broader STI ecosystem. According to the UNESCO Science Report (2021), most African countries understand the importance of STI to foster more inclusive growth and sustainable development. In response, many countries have or are developing STI policies; making financial commitment to R&D and intensifying efforts to strengthen private sector in their contribution to the overall function of national systems of innovation. Further, towards the spirit of achieving the SDGs, Africa is embracing sustainable development and examples abound of strategies and operational projects related to decarbonisation. Despite this, the economic diversification remains hampered by relevant innovation and development research skills shortage. Lema et al (2021) argue that there is very little innovation policy research conducted on the continent of Africa and what little there is has been concentrated in only middle-income incomes (e.g. South Africa, Botswana, Namibia) and a few lower-income countries, such as Ethiopia, Kenya and Nigeria. Diyamett (2021) on her part argues that the recent reorientation of innovation studies that seem to be aligned exclusively to addressing social and environmental issues – while relevant – may jeopardise Africa's efforts to build her capacity to build innovation systems that is also good for economic development. Both papers call for an urgent need to build Africa's capacity in socially relevant I&D fields. Given this context, it is crucial to place STI research and investment at the forefront of Africa's development agenda (Kraemer-Mbula and Wamae, 2010), ensuring that innovation and development efforts not only address pressing social and environmental challenges but also strengthen the continent's capacity to build robust innovation systems that drive economic diversification and long-term growth.

4.1.3 Research Capacity in iInovation and d=Development in Tertiary Education

Capacity building in I&D research – just like any other area of research – must start with formal training at universities. In this regard, while there is a good number of universities in the global North that carry out I&D research, extremely few universities in Africa have teaching curricular specifically focused on this field. This notwithstanding, however, there is a

5 See Fagerberg (2009) and Martin (2012) for discussions on Innovation Studies as an emerging field. For a recent discussion of Innovation Systems research using data from Scopus and Web of Science, see e.g. Rakas and Hain (2019). Further discussions on "innovation and its relations to sustainable and inclusive development" are discussed in a special issue of the journal *Innovation and Development*'s 10-year anniversary issue published in 2021. The papers in this special issue, including a paper by Lema, Kraemer-Mbula and Rakas (2021) on the status of the field, focus on the global level.

proliferation of training programmes that are somehow related to this field – indicating a great potential to easily introduce the teaching of this subject at universities. Two baseline studies conducted within the AfricaLics network[6] in 2014 and 2019 to understand the extent to which training and teaching programmes on innovation and development are offered within African institutions gleam a rough picture. The studies show that there is a proliferation of such training programmes in Africa indicating a growing academic community in this scientific field. The Master programmes appeared to be the most frequent type of training offered, followed by PhDs, short academic /research courses and training courses for policy makers. As for the PhD programmes, the majority fall under Social Sciences and particularly in the fields of Economics, Technology Management, Development Studies and Innovation Studies[7]. However, there are some innovation-related PhD programmes in Humanities, such as Education Studies, Information Sciences and Philosophy, as well as Natural Sciences (Telecommunications, Food Science, Chemical Engineering, ICTs, etc). This gives us an indication of how dispersed the research community is in this field and the need for specialised PhD programme targeted at analysing national systems of innovation and related fields.

4.1.4 Research and Publication in Innovation and Development Research

A lot of the research in the field of innovation and development conducted by African scholars remain largely invisible if conventional bibliometric methods are applied. This is due to the low number of African publications cited in what might be called 'mainstream' bibliometric databases such as Scopus and/or Web of Science[8].

A recent attempt to track publication efforts in this area within the innovation and development community in Africa, revealed that, innovation policy research is highly interdisciplinary field (Lema et al, 2021). The authors note that scholars focus on much more than just the evolutionary economics of innovation systems thinking but do include areas that fall more into management and business studies. What brings these otherwise often differing fields together is the focus on issues of development. In addition, this research focus policy attention at sectoral levels (e.g. health, agriculture, gender, education, energy, climate change policies) but also at STI policies and industrial policy more generally (Hanlin et al, unpublished[9]).

4.1.5 Major Challenges Around Duilding I&D Research Capacity in Africa

Major challenges seem to revolve around clear understanding of the role of I&D research in social and economic development among university leaders and policy makers in the countries, which seems to have led to allocation of very little financial resources for research capacity building in this field. The lack of expertise and theoretical grounding in I&D, must have led to poor understanding of the interrelationships in the popular triplet of science, technology and innovation (STI) in most Africa countries. For instance, it is common for both academics and policy makers to refer to this triplet as if it is one thing – people talk of STI capacity building, STI funding, forgetting that the three individual components in the triplet takes place in three distinct institutions. While science happens at universities, R&D can happen either in R&D institutions – including universities and the private productive companies. Innovation on the other hand is an avenue for the productive sector and calls for rethinking the broader and narrow sense of the national innovation system. The major problem arising from this erroneous understanding of the triplet of STI as one thing, is exclusive focus on universities and R&D institutions, forgetting where innovation happens – at the productive sector. Interestingly, even if people refer to research to generate

6 The African Network for the Economics of Learning, Innovation and Competence Building Systems (AfricaLics) is an academic research and capacity-strengthening network that focuses on how innovation occurs and the relationship it has with economic and social development in African countries (www.africalics.org). AfricaLics organises annual PhD academies to support the training of African doctoral students engaged in research in the field of 'Innovation and Development'.

7 PhD programmes explicitly dedicated to Innovation and Development in 2025 include: DPhil in Innovation and Development (University of Johannesburg), South Africa and a PhD in Innovation and Sustainable Development at Jaramogi Oginga Odinga University of Science and Technology (JOOUST) in Kenya. Other PhD programmes have a focus on Innovation in connection to Business Management, Entrepreneurship, Technology Management or Agricultural and Rural Development.

8 Lema et al (2021) use information from Web of Science and find that despite the substantial increase in the literature on innovation in developing countries in the social science disciplines (four-fold increase from 2000-2019), the bulk of this literature is still on middle-income emerging economies and only 57 papers identified came from low-income countries

9 Most countries show trade imbalances, with imports typically exceeding exports.

evidence for innovation policy, the major focus is still on natural and engineering sciences, forgetting research on I&D which is in the field of social science.

The above situation has been made worse by lack of funding for I&D research. This has been a major hindrance to efforts by AfricaLICS to build Africa's capacity in this area, since the resources for I&D research is neither available from the governments, private sector nor from the donors. In this regard, what policy makers need to understand is, without I&D research, it is very difficult to get the national R&D policy and commercialisation of research right. A good and impactful R&D policy must be informed by I&D research.

4.1.6 Conclusions and Recommendation

There is currently a momentum in contextualising innovation system to fit the African realities. To keep this momentum going, STI, research and education policies need to facilitate further progress. African based funding agencies, including national research councils, need to prioritise and increase funding for I&D. They should seise opportunities for multicountry research projects in the social sciences generally and including the field of Innovation and Development. In so doing, they may want to link up with external agencies that have a strong interest in supporting research and research capacity building on the continent, like the Swedish International Development Agency (SIDA). This type of research is even more important in view of the increased social and economic challenges that African countries are currently facing due to climate change and external factors like the Covid-19 pandemic (Kraemer-Mbula et al, 2023). Further development of African based research aimed at fostering sustainable and just solutions are as needed as ever. For regional/local as well as external actors it is crucial to maintain and increase support for initiatives and research on innovation and development that adopts the social science perspective.

Continent level initiatives are also needed to develop knowledge that would help build and strengthen African innovation systems to serve Africa's development. Such initiatives include the AfricaLics network whose efforts related to fostering collaborative research and publications should be supported towards enhanced capacities of African universities in I&D research.

However, to be able to succeed in all the above, it seems making African leaders (through advocacy) understand the role of policy in building national and regional STI capabilities and the role of evidence in the process so that there is incentive to design and implement policies correctly. This should be a starting point, otherwise, mere emphasis on the evidence for policy and need for I&D research will be a futile effort. This is because, according to Diyamett (2023), although many African countries have now STI policies, these are largely not implemented and are not aligned to the STI programmes that are running in the countries.

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4.2 SCIENCE, TECHNOLOGY AND INNOVATION POLICY AND INDUSTRIALISATION AT REC LEVEL

4.2.1 Background

This section examines the critical role Regional Economic Communities (RECs) play in promoting Science, Technology and Innovation (STI) for industrialisation across Africa. The African Union recognises eight Regional Economic Communities (RECs) as crucial building blocks for continental integration and development. It's important to note that some countries hold memberships in multiple RECs. Here's each REC, with the number of Member States (including potential overlaps): (1) the Economic Community of West African States (ECOWAS): 15 countries; (2) the East African Community (EAC): six countries; (3) the Southern African Development Community (SADC): 16 countries; (4) the Common Market for Eastern and Southern Africa (COMESA): 21 countries, (5) the Arab Maghreb Union (AMU): five countries; (6) the Intergovernmental Authority on Development (IGAD): eight countries; (7) the Economic Community of Central African States (ECCAS): 11 countries; (8) the Community of Sahel-Saharan States (CEN-SAD): 18 countries.

While individual African countries increasingly recognise the importance of S&T, RECs offer a broader regional approach with significant advantages. This paper explores the benefits of regional collaboration in STI, the current landscape of STI policy across RECs and the challenges and opportunities of industrialisation in these regions.

4.2.2 The Advantages of a Regional Approach to STI

While individual African countries are actively integrating Science and Technology (S&T) into their national industrial policies, RECs are playing a crucial role in fostering a broader regional approach to science and technology. This regional approach offers several advantages over individual national efforts in promoting STI for industrialisation:

- **Synergy and resource sharing:** by pooling resources from Member States, RECs can invest in larger-scale research projects and infrastructure development that might be beyond the capacity of individual countries. This synergy and resource sharing help to avoid duplication of efforts
- **Reduced duplication of efforts:** RECs can also facilitate the coordination of research efforts and the sharing of best practices, preventing Member States from duplicating research and development activities. This not only saves resources but also accelerates advancements across the region
- **Harmonisation of policies and standards:** additionally, RECs can work towards harmonising STI policies and standards across Member States. This creates a more predictable and investor-friendly environment for regional industrial development
- **Joint problem-solving:** furthermore, RECs can facilitate collaboration in addressing common regional challenges, such as food security, water management and climate change. By working together, Member States can leverage STI to develop and apply solutions that benefit the entire region

4.2.3 RECs as Catalysts for Industrialisation

As industrial development is seen as a key driver of African growth and poverty reduction, RECs are crafting and implementing targeted strategies to stimulate industrial activity across the continent.

- **Establishing free trade areas:** RECs prioritise the creation of free trade areas, aiming to eliminate tariff and non-tariff barriers that have historically impeded intra-African trade. This facilitates market access for African businesses, granting them entry to a vast continental market exceeding one billion consumers. This expanded market size fosters economies of scale, potentially leading to increased production, lower prices and ultimately, a more competitive African industrial sector. As part of their mandate RECs serve as instruments which can accelerate the African Continental Free Trade Area (AfCFTA) which is one of the flagship projects of the African Union (AU) Agenda 2063: The Africa We Want
- **Developing infrastructure:** recognising the critical role of infrastructure in economic development, RECs are actively involved in building a robust network of roads, ports, railways and energy facilities. Many RECs are working on integrating their national power grids. This allows countries to share electricity resources, which can improve reliability and affordability. For example, the East African Power Pool (EAPP)[10] is a regional institution established in 2005 to coordinate cross-border power trade and grid interconnection among nations of the Eastern Africa region. Another example is the SADC North South Corridor Project, which aims to improve transportation links between countries like Zambia, Democratic Republic of Congo and South Africa
- **Strengthening technological capabilities:** RECs acknowledge the importance of a skilled workforce and a robust research and development (R&D) ecosystem for sustained industrial growth. By actively developing technical skills through training programmes and fostering R&D initiatives, RECs empower African companies to adopt and adapt innovative technologies. For instance, the EAC Regional Centre for Information and Communication Technology (EAC-RICTA) works to improve access to ICT and foster regional collaboration by providing training programmes on ICT for government officials and businesses, developing regional policies and strategies for ICT development and facilitating the deployment of broadband infrastructure across the region. A second example is the SADC Regional Space Programme which aims to harness space technology for regional development. It includes projects like developing a regional Earth observation satellite constellation to monitor environmental changes and natural disasters and building capacity for space science research and applications

4.2.4 STI Policy Landscape Across Eight RECs

The landscape of STI policy across Africa's RECs reveals a mixed picture with promising developments but also room for improvement. While some RECs have established frameworks (ECOWAS, EAC, SADC), others rely on initiatives (COMESA) or are still in the development stage (AMU). This diversity reflects the unique challenges and priorities faced by each region. The level of STI policy development varies considerably across RECs.

EAC and ECOWAS stand out with their well-dedicated STI policies. The EAC's 2022 STI policy focuses on fostering an innovation ecosystem, intellectual property rights and inter-state collaboration. Similarly, ECOWAS's 2012 policy "ECOPOST" emphasises promoting scientific awareness, technology transfer and intellectual property protection. These policies position these RECs to leverage STI for regional economic growth. COMESA and SADC showcase a strong emphasis on collaboration. COMESA's initiatives highlight regional cooperation in STI, while SADC's 2008 Protocol prioritises collaboration for sustainable development and research infrastructure. This collaborative approach ensures that no single member state is left behind in the STI race. The (UMA) is actively developing an STI policy focused on research collaboration and technology transfer, crucial for addressing shared challenges like water scarcity and agricultural development. Similarly, the Community of Sahel-Saharan States (CEN-SAD), while lacking readily available information, likely prioritises areas like desertification control, drought mitigation and renewable energy – issues critical for the region's well-being. Limited information surrounds the STI policies of the Intergovernmental Authority on Development (IGAD) and the Economic Community of Central African States (ECCAS). However, based on regional needs, IGAD's focus might

10 https://eappool.org/

lie in disaster risk management, food security innovation and climate change adaptation, while ECCAS could prioritise healthcare delivery, digital technology access and sustainable resource management. Further investigation is needed to solidify these possibilities.

4.2.5 Role of STI in RECs' Industrialisation

All four RECs' industrialisation policy analysed in this sub-section – COMESA, ECOWAS, EAC and SADC – recognise STI as a crucial engine for industrial development (table 1). This recognition translates into a shared focus on building capacity for research and development (R&D), promoting innovation and fostering collaboration between research institutions, industry and academia. Additionally, all four RECs acknowledge the importance of technology transfer and adoption to close technological gaps and enhance regional competitiveness. Furthermore, human capital development through knowledge sharing, skills development and capacity building features prominently within each REC's industrial strategy. However, the approaches to achieving these shared goals diverge in some key aspects.

- COMESA stands out for its explicit encouragement of Member States to integrate STI policies with their industrial policies. This focus on policy coherence contrasts with the other RECs, where the emphasis lies on collaboration and capacity building within existing frameworks
- The specific areas of emphasis within each REC's strategy also reveal distinct approaches. COMESA leans towards regional collaboration in technology transfer and strengthening innovation ecosystems. ECOWAS places a strong emphasis on establishing technology parks and disseminating research findings directly within industries. The EAC highlights the role of the private sector in implementing and monitoring industrialisation policies, potentially fostering a more market-driven approach. SADC, on the other hand, integrates STI considerations throughout its strategy, focusing not just on capacity building but also on technological upgrading, environmental sustainability and establishing specialised research centres
- The level of detail and the presence of concrete action plans also vary across the RECs. COMESA and ECOWAS exhibit a more specific and action-oriented approach, outlining timelines and initiatives for capacity building, collaboration platforms and promoting specific technologies. In contrast, the EAC and SADC have broader strategies that emphasise the importance of STI but leave more room for member state interpretation and implementation

Below are the industry policy instruments under implementation in some RECs.

- EAC: East African Community Industrialisation Policy (2012)[11]
- SADC: SADC Industrialisation Strategy and Action Plan (2015-2063)[12]
- ECOWAS: West African Common Industrial Policy (WACIP)[13]
- COMESA: COMESA Industrialisation Policy & COMESA Industrial Strategy[14]

4.2.6 Challenges and Opportunities

While the RECs recognise the potential of STI, translating policies into tangible results presents main challenges:

1. **Implementation and monitoring gap:** effectively implementing STI policies and diligently monitoring progress towards set goals remains a challenge for many RECs. This requires strong political will from Member States, coupled with adequate resource allocation and the establishment of robust monitoring mechanisms to track progress and identify areas for improvement
2. **Financing the future:** securing sufficient funding for research activities, infrastructure development and capacity building initiatives remains a significant hurdle. Exploring innovative financing mechanisms, such as public-private partnerships, becomes crucial to bridge this resource gap and unlock the full potential of STI

11 http://repository.eac.int/bitstream/handle/11671/542/Final_EAC_Industrial_Strategy_edited%20final-%20FINAL-17-04-2-12.pdf?sequence=1&isAllowed=y
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3. **From labs to production lines:** bridging the gap between scientific advancements and their practical application within Member States' industries is another obstacle. Efforts are needed to foster stronger linkages between research institutions and the private sector to ensure that valuable research findings translate into practical applications that drive industrial growth

Despite the challenges, numerous opportunities exist for RECs to leverage STI for industrial development:

1. Regional synergy:

- **Specialisation:** foster industrial hubs in specific sectors by identifying regional strengths and encouraging member state specialisation
- **Joint R&D:** pool resources for large-scale research projects tackling common challenges

2. Fostering Iinnovation and technology transfer:

- **Technology transfer mechanisms:** establish channels to transfer existing technologies from developed regions to REC industries
- **Innovation ecosystems:** cultivate a culture of innovation through public-private partnerships, science parks and entrepreneurship initiatives

3. Building capacity:

- **Regional skills development:** standardise training programmes across RECs to create a skilled, mobile workforce
- **Infrastructure investment:** prioritise R&D for improved transportation, energy and communication infrastructure

4. Enabling environment:

- **IP protection:** harmonise IP laws to incentivise private sector R&D investment
- **Financing mechanisms:** explore innovative financing options like public-private partnerships and foreign investment

5. Addressing regional challenges:

- **Tailored STI policies:** focus research on overcoming specific regional hurdles like food security or energy shortages

4.2.7 Conclusion

Despite the variations in approach, all RECs acknowledge the importance of STI for industrial development. Opportunities exist to leverage these combined strengths and address regional challenges through fostering greater collaboration and knowledge sharing. By learning from each other's experiences, for example, COMESA's regional technology transfer hubs could be adapted by other regions. Pooling resources for large-scale R&D projects in areas of common interest could accelerate regional scientific advancement. Additionally, harmonising intellectual property frameworks and STI policies across RECs could create a more predictable and investor-friendly environment for industrial development. By working together, these RECs can transform STI into a powerful driver of sustainable and inclusive industrial growth across Africa.

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4.3 STATE OF AU MEMBER STATES' STI POLICIES

4.3.1 Background

4.3.1.1 The Lagos Action Plan: A Milestone in African Science and Technology Policy

In 1980, the Organisation of African Unity (OAU) took a significant step forward in promoting science and technology on the continent with the adoption of the Lagos Action Plan. The Lagos of Action Plan recognised the critical role of investing in scientific research, technology transfer, education and industrial development in propelling Africa's progress. It outlined a comprehensive programme and set of actions aimed at harnessing science and technology for economic growth, social development and improved living standards across the continent. One of the key initiatives proposed by the Plan was the establishment of national science and technology centres in each member state. These centres were envisioned as hubs for scientific research, technology development and the application of science to address Africa's unique challenges. The Lagos of Action Plan emphasised the importance of these centres being capable of formulating a clear and explicit national science and technology policy. This policy would translate to each member state's broader socio-economic development strategy into concrete technological lines of action, ensuring a focus on indigenous elements and solutions tailored to Africa's specific needs.

The Lagos Action Plan laid the groundwork for Africa's long-standing commitment to leveraging S&T for development.

4.3.1.2 The Consolidated Plan of Action: Boosting Africa's Science and Technology Policy Landscape

In 2005, the Africa`s science & technology Consolidated Plan of Action (CPA) marked another significant milestone in Africa's journey towards robust science, technology (S&T) policies. CPA is the first explicit S&T Policy adopted by the Continent through a political and public process involving several actors. The Plan has served as the roadmap for putting into action the decisions made at the first African Ministerial Conference on Science and Technology (AMCOST) in Johannesburg (2003). The plan identified a crucial gap related to S&T Policy development in Africa. It highlighted the fact that: "Several African countries lacked explicit national STI policies. Though some had policies dating back to the 1970s and 1980s, these no longer reflected the realities of globalisation and the continent's evolving economic needs. Additionally, limitations like weak oversight and adaptation hindered their implementation (NEPAD 2005)". To address these challenges, the CPA focused on improving the conditions for promoting technological innovation through programme such as the African Science, Technology and Innovation Initiative (ASTII) and AOSTI. It supported: (1) Developing national and regional STI policy frameworks, (2) Building capacity of STI institutions and (3) Enhancing STI skills.

4.3.1.3 The STISA-24: Accelerating the Transition of African Countries to Innovation-led and Knowledge-based Economies

From 2006 to 2010, the CPA's implementation has enabled the introduction of several flagship initiatives across the continent. However, most of these programmes were in the realm of science and technology. No mention was made of the innovation aspects. Furthermore, there was no mechanism for monitoring and evaluation. This made evaluating the plan in terms of accomplishments and contributions to the continent's socioeconomic development challenging.

As a result, in 2014, the AU adopted a new strategy, the African Strategy for STI (STISA), whose slogan "On the wings of innovation" and mission "Accelerate the transition of African countries to innovationled and knowledge-based economies" emphasise the importance of innovation in achieving Agenda 2063's "the Africa we want" development goals. Since its adoption, STISA has become one of the political foundations on which African countries have built their STI policies at the national level since its inception.

Following a comprehensive evaluation of STISA-2024, experts and stakeholders are now channelling their efforts towards developing the next iteration of the strategy: STISA-2034. The evaluation's valuable insights will guide them in crafting a more effective approach to harnessing science, technology and innovation for Africa's industrial growth.

4.3.2 The Importance of STI for Development

Currently, STI plays crucial roles in the national development strategies of many African countries, aligning across international frameworks such as the UN's 2030 Agenda for Sustainable Development Goals and the African Union's Agenda 2063 "The Africa We Want". For example, Angola has enshrined the importance of STI in its Constitution, recognising it as vital for building a modern and economically competitive knowledge society. Similarly, Egypt has integrated STI into its long-term development strategy, exemplified by the Sustainable Development Strategy: Egypt's Vision 2030, outlining a strategic vision for advancing knowledge, research and innovation. Conversely, Zambia aims for middle-income prosperity by 2030, with STI as a cornerstone of national development, as outlined in Zambia Vision 2030. Senegal's Emerging Senegal Plan (PSE) identifies STI as pivotal for economic diversification and modernisation, focusing on six priority sectors for STI investment. In Kenya Vision 2030, STI integration is essential for driving economic growth and sustainable development across sectors like agriculture and healthcare. Botswana's Vision 2036 emphasises increased STI investments for transitioning to a knowledge-based industrialised economy, prioritising innovation, research and development.

While the incorporation of STI in development plans varies across African countries, common themes include Economic Diversification, Education and Skill Development, Infrastructure Development, Industrialisation, Agricultural Transformation, Healthcare Improvement, Environmental Sustainability and Global Competitiveness.

4.3.3 Development of STI Policies in AU Member States

4.3.3.1 Advancing Science, Technology and Innovation Policies in Africa: a Decade of Progress

In recent decades, African countries have seen significant strides in the development or revision of Science, Technology and Innovation (STI) policies. Out of the 55 Member States of the African Union, it's notable that 41 have either developed or revised STI policies, with 24 of them doing so since 2014. This surge in policy formulation or revision followed the establishment of the African Union, coupled with various initiatives undertaken at regional, continental and international levels, with support from technical and funding partners such as UNESCO, Sida (Sweden), UNCTAD and IDRC, among others.

Among the regional initiatives, notable ones include the African Science, Technology and Innovation Indicators (ASTII) Project initiated by the New Partnership for Africa's Development (NEPAD), the establishment of the African Observatory of Science, Technology and Innovation (AOSTI), as well as the creation of the Pan African University. These initiatives have bolstered the STI capacities of African countries by providing reliable data, fostering regional cooperation and facilitating dialogue among stakeholders. This has played a vital role in shaping STI policies in Africa. Additionally, the inclusion of STI in financing for the Sustainable Development Goals (SDGs) has promoted the emergence of STI policies and strategies.

RECs notably the Common Market for Eastern and Southern Africa (COMESA), the Economic Community of West African States (ECOWAS), the East African Community (EAC) and the Southern African Development Community (SADC) have also played a crucial role in promoting Science, Technology and Innovation through regional policies focusing on S&T, creating collaborative programmes to foster research and innovation, as well as efforts to strengthen scientific cooperation among member countries (Mugabe, 2009; Mihyo, 2011).

4.3.3.2 Landscape of STI Policies in African Countries by Theme, Country and Region

The distribution of STI policies across African countries, as depicted in Figure 1, offers insights into the thematic and regional disparities in policy development. This analysis delineates the prevalence of various policy themes, including Science and Technology (S&T) policies, Research and Development (R&D) policies, Research and Development and Innovation (R&D and I) policies, Innovation policies and those pertaining to Education/Higher Education and R&D.

Primarily, the examination reveals a concentration of explicit STI policies in Southern African nations, indicative of a robust emphasis on technological advancement and innovation strategies within this region. Following closely are West African countries, notably Nigeria, Togo, Ghana, Niger and Mali, which exhibit considerable attention to STI policy formulation. In East Africa, Rwanda, Uganda, Kenya and Ethiopia demonstrate a moderate presence of STI policies, while Libya and Egypt represent Northern Africa in this regard.

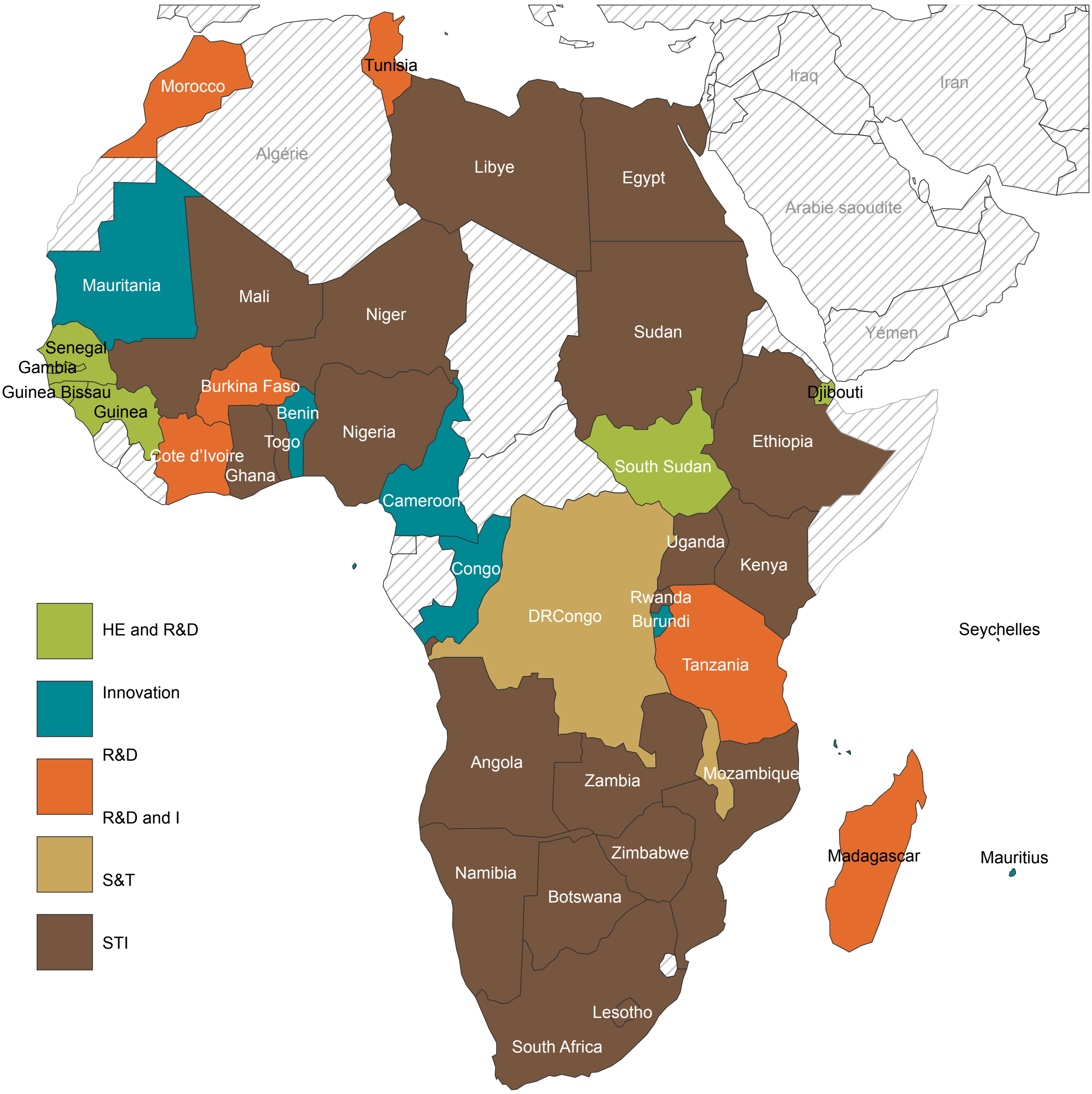
Further analysis discerns a prevalence of Research and Development and Innovation (R&D and I) policies, particularly notable within Francophone nations, totalling four in number. R&D policies, on the other hand, exhibit a broader distribution across Northern (Morocco and Tunisia), Eastern (Tanzania and Madagascar) and Western (Burkina Faso and Côte d'Ivoire) African regions. These findings underscore a nuanced landscape of policy emphasis. They are followed by Science and Technology (S&T) policies and Higher Education and R&D policies which are less represented. The significant representation of explicit STI policies, particularly notable in Southern African nations, underscores a concerted effort toward fostering technological advancement and innovation across the continent. This emphasis reflects a recognition of the pivotal role played by science, technology and innovation in driving economic growth, enhancing competitiveness and addressing developmental challenges.

The observed differences in the distribution of STI policies can be attributed partly to varying interpretations of STI concepts and the mandates of ministries or departments responsible for scientific, technological and innovation activities. Furthermore, it is noteworthy that while there is a significant presence of STI policies, many tend to prioritise Research and Development (R&D) over innovation. This imbalance may stem from a misunderstanding of innovation concepts and the associated policy design. As highlighted by Konté and Ekpe (2023), the prevalence of R&D-centric policies at the expense of innovation initiatives underscores the need for a more nuanced understanding of innovation dynamics and the incorporation of effective policy frameworks to foster innovation ecosystems.

4.3.3.3 Alignment of National STI Policies Across STISA – 2024

Aligning national policies and strategies with the Science, Technology and Innovation Strategy for Africa (STISA) is crucial for addressing continental development goals requiring an STI response. This alignment ensures that national priorities are in sync with regional, continental and global challenges. Both vertical coherences, managing connections across different levels and horizontal consistency, ensuring attention to all related objectives, are essential. To avoid inconsistency, every goal should be considered during this process. Since the adoption of STISA-2024, several countries have adjusted their national STI policies to align with the continental strategy. For instance, Mali, Uganda and the Democratic Republic of Congo have endorsed national policies and frameworks that incorporate STISA principles. South Africa, a key proponent of CPA, continues to promote STI development in Africa through AU strategies and regional integration efforts within SADC (DST 2019). South Africa's science diplomacy emphasises STI as crucial for AU and SADC development priorities. Meanwhile, countries like Egypt have oriented their policies towards the Sustainable Development Goals 2030 Agenda, although they still reflect AU STI strategies despite not explicitly mentioning STISA.

Figure 4.3.1 Geographical distribution of policies (relating to STI) by area



Source: authors, March 2024

4.3.4 STI Policy Governance

4.3.4.1 Governing Bodies

Observation of the landscape of STI institutions in Africa reveals that most countries have ministries mandated for this purpose. The terminologies used to designate these ministries vary from one country to another (Table 4.3.1).

Table 4.3.1 Ministry responsible for STI in AU member countries implementing explicit STI policy.

COUNTRY	MINISTRY/INSTITUTION RESPONSIBLE FOR STI
Angola	Ministry of Higher Education, Science, Technology and Innovation
Benin	Ministry of Higher Education and Scientific Research
Botswana	Ministry of Communications, Knowledge and Technology
Burkina Faso	Ministry of Higher Education, Scientific Research and Innovation
Burundi	Ministry of Education and Scientific Research
Cameroon	Ministry of Scientific Research and Innovation (MINRESI)
Congo	Ministry of Higher Education, Scientific Research and Technological Innovation
Cote d'Ivoire	Ministry of Higher Education and Scientific Research
Djibouti	Ministry of Higher Education and Research
Congo, D.R.	Ministry of Scientific Research and Technological Innovation, changed to Ministry of Higher Education, Scientific Research and Technological Innovation (August 2025)
Egypt	Ministry of Higher Education and Scientific Research
Ethiopia	Ministry of Innovation and Technology
Gambia	Ministry of Higher Education, Research, Science and Technology
Ghana	Ministry of Environment, Science, Technology & Innovation
Guinea Bissau	Ministry of Higher Education, Scientific Research and Innovation
Guinea	Ministry of Higher Education and Scientific Research
Kenya	Ministry of Higher Education, Science Technology
Lesotho	Ministry of Communications, Science and Technology
Libya	National Planning Council
Madagascar	Ministry of Higher Education and Scientific Research
Malawi	Ministry of Education, Science and Technology
Mali	Ministry of Higher Education and Scientific Research
Mauritania	Ministry of Higher Education and Scientific Research
Mauritius	Ministry of Technology, Communication and Innovation
Morocco	Ministry of Higher Education, Scientific Research and Innovation
Mozambique	Ministry of Scientific and Technology, Higher Education and Professional Training, changed to Ministry of Education and Culture (MEC) since February 2025
Namibia	Ministry of Higher Education, Technology and Innovation
Niger	Ministry of Higher Education, Research and Technological Innovation
Nigeria	Federal Ministry of Science, Technology and Innovation
Rwanda	National Council for Science and Technology
Senegal	Ministry of Higher Education, Research and Innovation
Seychelles	Ministry of Investment, Entrepreneurship and Industry
South Africa	Ministry of Higher Education, Science and Innovation
South Sudan	Ministry of Higher Education, Science and Technology
Sudan	Ministry of Higher Education and Scientific Research
Tanzania	Ministry of Communication, Science and Technology
Togo	Ministry of Higher Education and Research
Tunisia	Ministry of Higher Education and Scientific Research

Uganda	Ministry of Science, Technology and Innovation
Zambia	Ministry of Technology and Science
Zimbabwe	Ministry of Science and Technology Development

Source: AIO-2024 authors – Feedback from ASTII National Focal Points & Member States of March 2024

This table provides a valuable overview of the government ministries or institutions responsible for Science, Technology & Innovation (STI) in various African countries. Here are some key observations:

- **Focus on higher education:** a significant number of countries (e.g. Benin, Congo, Egypt) list the Ministry of Higher Education or a similar body as responsible for STI. This suggests a connection between scientific advancement and universities
- **Dedicated "STI" ministries:** several countries have established dedicated Ministries for STI, such as Uganda's "Ministry of Science, Technology and Innovation" or Nigeria's "Federal Ministry of Science, Technology and Innovation", Zambia's "Ministry of Technology and Science". This indicates a strong national emphasis on these fields
- **Variations in terminology:** there is some variation in the specific names of the responsible ministries. Some use terms like "Research" or "Scientific Research" alongside "Higher Education" or "Science"
- **Independent bodies:** a few countries, like Rwanda with its National Council for Science and Technology, have separate entities overseeing STI, potentially indicating a more specialised approach. Zambia also has an independent body under the Ministry of Technology and Science called the National Science and Technology Council (NSTC)

Even though a ministerial department serves as the primary governing body, the complexity and interdisciplinary nature of STI policies necessitate collaboration with other ministries or bodies responsible for strategies and programmes affecting STI. In Ethiopia, technical and vocational education and training institutions (TVETs) and two technological universities have been established as part of initiatives to strengthen STI education. In Rwanda, various bodies such as the Ministry of Education, the Ministry of Youth and Information and Communication Technologies, the National Council for Science and Technology (NCST) and the National Industrial Research and Development Agency (NIRDA) are involved.

4.3.4.2 Institutional Instability

In some countries, there is notable instability in the evolution of ministries responsible for STI. This is evident in the case of the DRC, where the Ministry responsible for scientific research, since its inception, has functioned intermittently as an autonomous ministry, sometimes merged with that of Higher and University Education and at times even with Primary, Secondary and Vocational Education (Ministry of National Education).

In Botswana, the institutional landscape and leadership for STI policy have undergone frequent changes, leading to uncertainty and discontinuity in strategic planning, potentially adversely impacting policy implementation. Between 1998 and 2016, the administration of the S&T policy (and its successor, the 2011 National Research, Science, Technology and Innovation Policy) transitioned from the Ministry of Finance and Development Planning (1998–2003) to the Ministry of Communications, Science and Technology (2004–2008), then to the Ministry of Infrastructure, Science and Technology (2008–2017) and subsequently to the Ministry of Tertiary Education, Research and Technology (2017–2022). In May 2022, it was relocated to the new MCKT. The table below illustrates the evolution of the Ministry with responsibilities for scientific research.

Table 4.3.2 Evolution of ministry responsible for STI policy from 1998 to 2022 in Botswana

Period	Ministry/department responsible for STI Policy
May 2022 onwards	Ministry of Communications, Science, Technology and Innovation (MCKT)
2017–2022	Ministry of Tertiary Education, Research and Technology
2008–2017	Ministry of Infrastructure, Science and Technology
2004–2008	Ministry of Communications, Science and Technology
1998–2003	Ministry of Finance and Development Planning

In the span of 26 years, Botswana has witnessed five changes in the Ministry or Department responsible for STI policy. This indicates a notable level of institutional flux and underscores the dynamic nature of STI governance within the country. Such frequent transitions may introduce challenges such as uncertainty, discontinuity in strategic planning and potentially hindered policy implementation. Moving forward, ensuring stability and continuity in STI policy leadership could be essential for fostering long-term coherence and effectiveness in Botswana's approach to science, technology and innovation.

4.3.4.3 STI Policy Cycle

The STI policy cycle in Africa is hindered by systemic issues, ranging from formulation to implementation, through monitoring and revision. Indeed, there is a sluggishness in the development of STI policies. A study conducted on the governance of STI policies in Central African countries showed that the formulation of STI policies is often characterised by isolated events, as illustrated by the case of Burundi where the policy was adopted in 2011, followed by the action plan in 2014, requiring three years for implementation. Other countries, such as the Democratic Republic of the Congo, experience significant delays in governmental decision-making for the adoption of their STI policies. This slowness is primarily attributable to a lack of financial resources, forcing most countries to rely on funding from partners such as UNESCO to initiate formulation or revision activities of STI policies. However, these funds often cover only one or two stages of the process, resulting in a halt once resources are depleted (Konté, 2022).

In addition to the lack of dedicated resources, countries face difficulties in formulating coherent and suitable policies, which can be attributed to complex decision-making processes and a lack of consensus. Projects and initiatives do not always come to fruition and alignment with defined objectives remains challenging.

Furthermore, the absence of effective monitoring and evaluation mechanisms is a major problem. Most countries lack formal mechanisms to assess progress in implementing STI policies, making it difficult to measure impacts and outcomes. Finally, inadequate coordination poses another challenge in the process of revising and reformulating STI policies. Most African countries lack adequate monitoring and evaluation mechanisms or the necessary capacities for the design and monitoring of STI policies (Essegbey et al, 2021 and AOSTI, 2013). This creates a significant gap that hampers the availability of data for evidence-based decision-making.

4.3.4.4 Recommendations

- **Strengthening innovation policy focus:** African governments should invest in capacity building initiatives and knowledge sharing to develop a deeper understanding of innovation policy and its effective implementation
- **Developing robust implementation plans:** each STI policy framework should be accompanied by a detailed implementation plan outlining clear objectives, timelines, resources and responsible stakeholders
- **Promoting intersectoral collaboration:** mechanisms should be established to ensure active participation and collaboration from all relevant sectors in the development, implementation and monitoring of STI policies.
- **Investing in M&E systems:** building strong M&E systems and enhancing institutional capacity for policy design and evaluation are essential for ensuring the effectiveness of STI policies and maximising their impact on development objectives

4.3.5 Conclusion

The African continent has made significant strides in the development and revision of Science, Technology and Innovation (STI) policies in recent decades. The establishment of the African Union and regional initiatives have spurred 41 out of 55 Member States to develop or revise their STI policies, with a notable surge seen since 2014. The evolution of STI policies in AU Member States reflects a shift towards aligning national policies with continental strategies like the Science, Technology and Innovation Strategy for Africa (STISA). While there has been progress in policy formulation or revision, challenges persist, such as delays in decision-making, lack of financial resources and the need for coherent and suitable policies. The lack of dedicated resources, proper coordination and effective monitoring and evaluation mechanisms hinder the successful implementation of STI policies. Moreover, the institutional landscape for STI policy governance in some countries shows instability and frequent changes in ministries responsible for STI, impacting strategic planning and policy implementation. Moving forward, addressing these challenges will be crucial to harnessing the full potential of STI for Africa's sustainable development and economic growth.

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4.4 FROM BEST-PRACTICE TO BEST-FIT: CONTEXTUALISING INNOVATION POLICY FOR TRANSFORMATION

4.4.1 Introduction

Our current time is marked by a sense of instability and uncertainty – and the challenges and opportunities that come with that. Many and major crises are upon us, including geopolitical tensions, a global economic slowdown, ongoing wars and environmental calamities. Simultaneously, for the African continent, it is also a time of opportunities. The economic and political interest and importance of Africa has increased across the globe, the "Africa rising" debate has contributed to an increased sense of optimism (The Economist 2011, Frankema and Van Waijenburg 2018) and the efforts made over the past decades in the realm of science, technology and innovation (STI) and data collection work provide clearer indications of what remains to be done to achieve Agenda 2063.

As such, the instability of our current times may be a window of opportunity or "critical juncture" (Collier and Collier 1991, Weingast 2005, Acemoglu and Robinson 2012), for innovation, industrialisation and prosperous transformation in Africa. However, a crucial requirement for innovation policy to successfully lead to such transformation is to ensure that policy and reality align and paying close attention to the contextualisation of the innovation policy. While the scholarly work on the connection between transformation and innovation policy is extensive, the successful design, implementation and evaluation of such policies is proving challenging (Schot and Steinmueller 2018, Schwaag Serger and Palmberg 2022). Importantly for the African context, there is also a gap in this literature with regards to if and how STI-policies should be different in high- and low-income countries (some exceptions include Freeman et al 1992 and Lundvall 2022). Considering this, the important question for implementing innovation policy that advances beneficial transformation is: how can STI policy be shaped to fit the on-the-ground socioeconomic reality? STI policy on its own cannot drive economic and societal transformation, but it can play one role of many in driving it. To be able to do so, it needs to take a holistic and society wide approach. Accountable, agile and competent governments are an important ingredient in this – as government engagement and support of STI, for initiation, investment, coordination etc. is crucial and necessary – but it is not enough. In this paper, we highlight three additional aspects that will be needed for STI to lead to successful societal transformation: (i) considering the context-specific conditions rather than a standard list of “necessary prerequisites”; (ii) enabling the private sector to be a co-driver of societally beneficial change and (iii) recognising the importance of place-based development across the local, national and pan-African levels.

4.4.2 Prerequisites for Transformation

Occasionally there are voices claiming that there are “necessary prerequisites” that must be met in a low-income country for socio-economic transformation to materialise. The list of items that at one point or the other was seen as an absolute must before development was to take-off is long. Throughout time we have seen availability of coal, a temperate climate, Protestantism, a strong middle class or well-defined property rights – just to name a few examples – as factors that were believed to be necessary before development could emerge (cf. Koyama and Rubin 2022 for an overview). However, if such a list was also empirically accurate, no country in history would have had a chance to catch up. Fortunately, the paths to transformative development are varied and a factor that might have been necessary for development in one context might not be present in another case that also succeeded. Things that are essential for long-term sustainable development might also emerge in the process itself, rather than having to be at hand before the onset of the process. This is both an important and reassuring insight from past development experiences. But without a blueprint recipe, things also become more complex.

Certain factors still seem highly critical for a transformation to be progressive, sustained and self-generating. A healthy, skilled and agile work force seems as important as ever, if not even more important in a digital and fast-moving age. This includes activating everything from “upper-tail knowledge” to “indigenous knowledge” (see e.g. Squicciarini & Voigtländer 2015 and Briggs 2005). Successful and wide adoption of technology still requires a skilled workforce, including technicians and engineers. Such a workforce is important for the prospect of technological catch-up and leapfrogging, not least considering the acute need to transition into new energy and green technologies, but also for stimulating labour intensive industry for generating competitive employment growth given the rapid urbanisation process and increasing youth population. Similarly, broad-based access to electricity and decent physical and digital infrastructure as well as well-functioning governance and reliable public services are conditions that most certainly play key roles.

Considering the above, when discussing industrialisation and innovation for socio-economic transformation there is a need to keep two things simultaneously in mind: (i) Some elemental conditions need to be in place and (ii) you need to work with what you have got. While the first mostly falls on part of the government, the latter implies smart use of the resources and competences there are at hand, which implies engaging and coordinating a multitude of stakeholders beyond the sheer capacity of the government. This means that there is a need to move away from “best practice” (striving to implement global state-of-the-art STI practices and policies) and instead focusing on “best fit” STI policy and implementation of. This is also in line with longstanding theoretical work that highlight that if imported technology, know-how, innovations etc., cannot be properly used in the importing context, they will not lead to progress (cf. Abramovitz 1986, 1995 and Andersson & Palacio 2017 on the role of “social capabilities”). As an empirical case in point, the domestic capacity for mimicking and modifying existing technologies was crucial for Japan’s transformation (see e.g. Hayashi 1984). Early on it required engineering skills in Japan to infuse traditional practices with modern technology to increase efficiency but also for absorbing new technology. Technical and engineering capabilities were not only important in Japan but a key factor at the onset of the industrial revolution in general (Mokyr 2005).

A similar divide between best practice/best fit applies also to data collection and the important work that organisations such as AUDA-NEPAD has done in collecting large amounts of relevant data in the field of innovation across Africa. Best practices in collection of data and assessing comparable indicators are of crucial importance for informing and guiding innovation policy. However, they might not be sufficient. Diagnosis of what you have can be equally important as counting things that are easy to compare across geographies and development contexts (such as R&D investments, publications, patents or numbers of PhDs). Making innovations transformative requires working with what you have – not only what you want – and making use of tacit knowledge – that is harder to quantify – might be equally evidence based. Not doing everything at once might be the smarter thing to do. You do not have to tread the bridges until you reach them. Tacit local knowledge and routines exist for a reason, often for dealing with scarcity and risks. Such tailor-made knowledge geared to specific circumstances might not be "innovative" and state of the art in the STI-literature sense of the word but can nevertheless be highly useful. Connecting back to our empirical example of Japan, shifting to advanced technologies from traditional should make use of the traditional knowledge rather than dismissing it. This was one of the keys of the relatively rapid and progressive transformation of Japan in its industrialisation process.

4.4.3 Prerequisites and Natural Resources

An important element in our call for "working with what you've got", is of course the state of initial conditions in a specific context, specifically with regards to factor and natural endowments. Considering a country's natural endowments and relying on natural resources as a path to progress has historically been risky and fraught with challenges such as the resource curse, corruption and misallocation of funds. However, there have also been instances of success in this approach. In countries like Canada, Australia and Norway, natural resources have indeed served as a solid foundation for progress and prosperity. The lessons drawn from these cases are that for this path of relying on natural resources to be a viable route to development, it needs to be coupled with a robust framework of social and institutional capabilities to ensure that the benefits of natural resources can be harnessed for the greater good of a region or country.

While natural resources need not be a curse, they are a challenging way forward. The important aspect is how to increase the value-added produced at home: and strengthening the domestic natural resource-sector could be a way forward, along the historically more common route of industrialisation. Another possible, often under-considered avenue is an agriculturally led development strategy (cf. Adelman 1984; Rohne Till 2022). The important aspects in such an approach are to increase productivity and domestic value added, regardless of the path chosen (industry, resources, high-productivity agriculture).

4.4.4 The Private Sector as a Co-driver of Transformation

Socio-economic transformation requires the involvement and mobilisation of multiple actors: the state, the business sector, civil society and broad segments of the population. While governments and policy formulation of course play a vital role for example in setting regulatory frameworks and allocating government resources, they do not operate in a vacuum and they are insufficient to drive transformation. Far-reaching socio-economic change for a more sustainable and prosperous future requires substantial changes in the modes of production and consumption and in the mechanisms or signals driving investments and markets and in social and cultural norms and behaviours (Benner, Schwaag Serger and Marklund, 2022; Weber and Rohracher, 2012). Without the support, investments and buy-in from industry, academia and society such changes are not likely to happen.

To understand how innovation policy can be shaped to create a self-generating process it seems important to also understand the institutional arrangements which underpin these dynamics. According to North (2005), the distinguishing factor in successful development examples is what he terms "adaptive efficiency." These institutions strike a balance between stability and the capacity for policymakers to enact reforms and adapt policy priorities in response to changing circumstances, akin to what Hirschman (1958) describes as "reform mongering." The policymaker needs what UNCTAD refers to as a suitable policy space that allows for this flexibility to choose appropriate policy (Jackson, 2021). Establishing these adaptable policy frameworks that lead to progressive and successful outcomes is an accumulative process where one development builds upon another, drawing from past experiences and accumulated knowledge. Crucially, it also allows for multiple stakeholders to play their role in this process.

In many low-income countries, not least in Africa, large multinational corporations (MNCs) are operating, often in the natural resource and commodity sectors. Linking up with these companies can prove to be a most important avenue for technology transfer and capacity building and for generating investments in and directing them towards up-skilling and transformation efforts. Greater efforts can be made to explore such linkages and potentials. This presupposes some extent of state autonomy visà-vis MNCs to reap the benefit of such presence through mutual interlinkage. For the private sector to be able to be a co-driver of transformation, a stable environment to operate in is one key aspect. To ensure this, work is needed for governments to convey credible commitments and signals (e.g. towards sustainability and transformation) encouraging businesses to invest; encourage multistakeholder (private and public) initiatives; and to build up support systems for innovative activities with, but also beyond, the state.

4.4.5 Recognising the Importance of Place-based Development

That "context matters" is almost a truism in social science – but nonetheless an important insight. The important challenge is to understand which context that matters. One aspect of "context" that deserves – and increasingly is receiving – specific attention, is the importance of place-based development. The prospects for STI policies to have their desired effect will vary significantly in different local, national and regional areas across the continent, with some places better positioned for success than others and with success taking on various forms. Given these challenges, the quest for finding the "appropriate technologies" regarding circumstances, linkages and efficiency, should not only be guided by a country's factor endowments and natural resources, but also be appropriate to the objective of transformation itself. This is influenced by several place-based characteristics, including economic and industrial structures, political and institutional set-ups, natural and factor endowments and technological and scientific capabilities. Not only geography or the extent of natural resources shape the prospects for a particular place, but also a wide range of these other factors (Maskell and Malmberg, 1999; Asheim et al, 2019; MacKinnon et al, 2019). In Africa, multiple layers of "place" and context will matter for success: the local, the national, as well as the pan-African context.

As one case in point, the production and access to energy is one sector where the importance of place-based development will become more important going forward. In the past era of relying on fossil fuels, industrial production has not been tightly linked to the place it is produced – but this may change with the green transition and increased use of renewable energy. Except for nuclear power, all non-fossil sources of energy – sun, wind, hydro and geothermal – display huge locational differences across the globe (Hausmann, 2021). Going forward, this could imply a possible relocation of industries near more easily accessible renewable energy sources. In turn, this could result in a radical shift in industrial production and the role of global value chains (as discussed by Soete and Stierna, 2023). If so, energy-intensive activities will again be much more location-dependent, in a fashion not seen since the early days of the first Industrial Revolution and the reliance on the water wheel.

4.4.6 Conclusion

The nature of successful STI policies is not universally given, but rather time and place dependent. In this chapter, we make a call for the importance of contextualising STI policies for transformation. Specifically, this includes an effort to bring nuance on the part of "best practices", in favour of "best fit". To be able to translate such a call into reality, there is a large need for information and data on the current context, so that policies can be contextualised accordingly. To date, AUDA-NEPAD and other actors have made much progress in this front, based on decades of effort under ASTII and other initiatives. The next step will be to thoroughly use this knowledge – now that it is evolving – to design policy that fits with and in its context. That said, while we argue that the list of "necessary prerequisites" does not need to be long, we highlight two prerequisites that do seem to be important and the lack of which may hamper progress: a healthy, skilled and agile work force and at least decent infrastructure, including electricity.

Our current time may be marked by instability, but it is also a time of opportunities for innovation-led socio-economic transformation in many parts of Africa. In this paper, we have highlighted three aspects of how to contextualise innovation policy, to strengthen its prospect to lead to societal transformation. These are to consider the context-specific conditions rather than a long list of "necessary prerequisites"; support the private sector as a co-driver of change; and recognise the importance of place-based development across the local, national and pan-African level.

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CHAPTER 5
RESEARCH AND EXPERIMENTAL DEVELOPMENT

5.1 BACKGROUND

This chapter examines Research and Development (R&D) expenditure patterns across African countries, revealing distinct national research strategies and development priorities. Through comprehensive analysis of R&D funding distributions and institutional sector data, the study identifies four main funding model archetypes: government-centric, diversified, aid-dependent and underdeveloped systems.

The analysis demonstrates fundamental differences in research approaches, from Rwanda's emphasis on basic or fundamental research to Mauritius's focus on applied research. These variations reflect different stages of scientific development and national priorities, with significant implications for long-term scientific capacity and economic development. The study finds that no African nation has yet achieved a business-sector-dominated R&D profile characteristic of developed economies, though countries like Egypt and South Africa show movement in this direction.

The chapter identifies critical cross-cutting themes, including the impact of economic scale inequality, structural challenges in research infrastructure and the systematic underinvestment in public non-profit research. A key finding is the correlation between gross domestic product (GDP) size and R&D expenditure levels, suggesting potential widening knowledge and innovation gaps across the continent.

The research culminates in policy recommendations addressing three main areas:

(i) strengthening R&D measurement systems across Africa
(ii) tailoring funding strategies to specific national contexts
(iii) enhancing regional collaboration and knowledge exchange

These recommendations aim to address the identified challenges while leveraging existing strengths within different national research ecosystems.

This study contributes to understanding African R&D systems by providing a novel classification framework and identifying potential development pathways for research systems across the continent. The findings have significant implications for policymakers, research institutions and international development partners working to strengthen Africa's scientific and technological capabilities.

R&D is an important contributor to the economic activities of any country. It facilitates policy formulation and elaborates on national strategies based on evidence. The objective of this chapter is to report the measurement of gross domestic expenditure on R&D (GERD) and associated personnel within African countries[15].

Defining Research and Experimental Development (R&D)

R&D comprise creative and systematic work undertaken to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge (OECD, 2015: 28, para 1.32). R&D activity encompasses all actions deliberately undertaken by R&D performers to generate new knowledge (OECD, 2015: 46, para 2.12).

15 The data is based on the submissions of countries that responded to the call to conduct R&D survey and provide data to be included in this report.

GERD is an aggregate expenditure on R&D activities performed on a national territory in a given year. It is obtained through R&D measurement covering the four traditional sectors of performance, namely (i) Business enterprises (BUS) of different sizes being State-owned and private ones including trade corporation; (ii) Government (GOV) covering public research institutes, commissions, council and national museums and botanical gardens; (iii) Higher Education (HE) with its public, private and confessional tertiary institutions; and finally (iv) Non-Profit Organisation (NPO) institutions or organisations including the first ladies, philanthropists and non-governmental organisations (NGOs) committed to research activities. The level of R&D performance differs from sector to sector and, from country to country depending on the objectives to undertake R&D within individual responding units within a stratum or a grouping and the availability of resources to perform R&D activities: census or sampling approach with an inference to reach and target population.

R&D personnel is the most vital component in R&D activities as it includes all people engaged directly in R&D, whether internal or external to the unit that is performing research as an integrated task (intramural R&D). Those who are indirectly involved are not involved in the headcount of personnel but only have their prorated costs added to avoid over-estimating the headcount. Even for those directly involved in R&D as Headcount, there is another calculation to track only the portion of time committed to R&D activities captured in calculating the Full-time equivalent salaries. The latter is part of the computation of the total R&D expenses within each statistical unit covered in the survey, cognisant of the extrapolation of the information of the sample to adjust to the target population in case the sector was too large to allow a census.

Countries get their data from coverage of national R&D surveys across sectors or the use of administrative data to improve the quality over time. The data collected is either over or under-estimated based on the data collection approach followed. However, R&D personnel is directly linked to its Full-time equivalent (FTE) portion presented as FTE salaries in the calculation of the overall R&D expenditure (current costs and capital expenditure).

The data gleaned from the R&D surveys and/or administrative data contribute to national totals of research and development activities. It is also used nationally and internationally by different stakeholders and international organisations for statistical analyses, benchmarking, comparability and policy purposes in alignment with national, regional, continental or continental frameworks, strategies or database.

This chapter focuses on R&D Personnel and GERD based on available statistical data in AU member countries. All countries were expected to submit R&D datasets. However, only ten national focal points made available their datasets with different reference periods to ASTII secretariat (AUDA-NEPAD), namely: Benin, Egypt, Ghana, Malawi, Mali, Mauritius, Nigeria, Rwanda, South Africa and Zambia. Furthermore, for various reasons, not all among the ten submitted the full dataset as stipulated in the outline of this chapter. Therefore, comparability may be challenging in some sectors or between countries experiencing issues related to the declining response rates in official surveys. The R&D chapter does not rank countries but provides a clear understanding of R&D performance in each country and where possible, relate the current and previous performances. These activities lead to identifying strengths and weaknesses, prompting an evaluation of existing policy imperatives, thereby prompting improvement or development of new R&D policies.

Why Measure R&D Activity?

R&D intensity is a measure of the level of research and development (R&D) activities that a country, sector or organisation puts in relative to the size of the economy. One such measure is to use the number of R&D personnel as a percentage of total employed people. However, the most common measure of R&D intensity is the ratio of Gross Domestic Expenditure on R&D (GERD) to Gross Domestic Product (GDP) (OECD, 2015: 144, para 4.162). This definition has the advantage of being defined in terms of expenditure items, which allows for easier integration into the extensive SNA framework, based on expenditure statistics.

Data and statistics on R&D assist policymakers and decisionmakers in understanding, monitoring and effectively managing financial and human resources allocated to R&D activities. These insights are useful to identify institutions or firms that are performing well, those that require support and the type of support that might be needed. The richness of the data provides analysts with the opportunity to identify the reasons why organisations require support. It also assesses the alignment of R&D activities with national development plan's objectives and priority areas such as manufacturing, energy, health, information and communication technology (ICT) and agriculture. Finally, it enables the setting of sector-specific, regional or country-level long-term R&D investment targets, chief among which is the R&D intensity.

R&D intensity, often expressed as the ratio of GERD to GDP, remains the main indicator revealing the importance and impact of R&D activities within a country's economy. The significance of R&D intensity can be understood through several key aspects.

Economic growth and competitiveness:

- **Innovation and productivity:** without being biased by the assumption of a linear model of R&D investment leading to innovation, higher R&D intensity in the fourth industrial revolution (4IR) and the fifth industrial revolutions (5IR) indicates a strong commitment to innovation, which can lead to increased productivity and economic growth. Being one of the innovation activities, investments in intramural or extramural R&D often result in new products or those significantly improved from one to several characteristics and new and significantly improved processes that enhance efficiency and competitiveness in the market or during utilisation
- **Economic resilience:** countries with higher R&D intensity tend to be more resilient to economic downturns, as they are better equipped to innovate and adapt to changing market conditions

Technological advancement:

- **Leadership in technology:** high R&D intensity often correlates with leadership in technological advancements and high-tech industries. Countries investing heavily in R&D are more likely to develop cutting-edge technologies and maintain a competitive edge in the aggressive global market
- **Patent generation:** greater R&D efforts typically lead to more patents and intellectual property in economic sectors where enterprises use IP protection as a competitive strategy. Examples of such sectors are pharmaceuticals and biotechnology, ICT, electronics and electrical engineering, agriculture and food technology and renewable energy and environmental technology. Such activities can provide economic benefits through licensing and commercialisation as part of intangible assets

Social and environmental benefits:

- **Healthcare and quality of life:** R&D in fields like pharmaceuticals and biotechnology or healthcare in general can lead to significant improvements in public health and quality of life. Innovations in medical instruments, treatments, diagnostics and preventive care are often the result of sustained R&D investments
- **Environmental sustainability:** R&D plays a crucial role in developing sustainable technologies and solutions to address environmental challenges. This includes advancements in renewable energy, energy efficiency, waste reduction and pollution control

Human capital development:

- **Education and skills:** high R&D intensity foster an environment that encourages education and the development of a skilled workforce. It creates demand for scientists, engineers and researchers, contributing to the overall intellectual capital of a country
- **Attracting talent:** countries with robust R&D activities are more likely to attract and retain top talent from around the world, further enhancing their innovation capabilities

Investment and funding:

- **Private sector investment:** evidence of a high R&D intensity can attract private sector investment by signalling a favourable environment for innovation and technological development. It indicates a country's commitment to supporting R&D through infrastructure, funding and policies
- **Government funding:** governments can use R&D intensity metrics to allocate resources effectively and justify increased funding for research institutions, tertiary institutions (universities, colleges, institutes, etc.) and public-private partnerships

Policy and strategic planning:

- **International comparisons:** R&D intensity provides the basis for international comparisons, helping countries with full R&D datasets understand their position relative to others. This can inform strategic decisions and encourage collaboration or competition in global innovation efforts
- **Policy benchmarking:** R&D intensity serves as a benchmark for policymakers to assess the effectiveness of their R&D policies and strategies. It provides a quantitative measure to evaluate the impact of government incentives, funding programmes and regulatory frameworks on R&D activities
- **Monitoring of R&D programmes:** time series of R&D intensity ensures that objectives are being realised or that deviations are detected and responded to

National Development Objectives and Industrialisation

National development plan (NDP) objectives and priority areas such as manufacturing, energy, health, ICT and agriculture are integral to industrialisation. They provide the necessary infrastructure, human capital and technological advancements that underpin sustainable industrial growth and economic development.

Manufacturing is the foundation of industrialisation, enabling countries to add value to raw materials, produce higher-value goods and boost export potential. Manufacturing hubs often drive innovation and technology transfer, essential for an accelerated industrialisation, inclusive of the industrial revolutions: 4IR and 5IR.

Being part of infrastructure, reliable and efficient energy sources are crucial for industrialisation, powering factories and machinery. Emerging economies often rely heavily on energy-intensive primary industries. Sustainable energy innovations ensure a steady supply while minimising environmental impact, critical for long-term growth. Developing energy infrastructure, like power plants and grids, supports industrial activities and attracts investment.

Improving healthcare ensures a healthy workforce, vital for industrial productivity and useful to improve life expectancy. The Covid-19 pandemic highlighted the potential of the pharmaceutical and biotechnology sectors to drive industrialisation through medical products and technologies.

ICT is the single most important general-purpose technology moving to the Internet of Things (IoT), one of the 10 emerging technologies prioritised by the AU high-level Panel on Emerging Technologies (APET). As such, it is crucial for modernisation and digital transformation, with the potential to accelerate automation, efficiency and innovation. ICT enables smart manufacturing with the Internet of Things (IoT), artificial intelligence (AI), Machine Learning (ML), blockchain and big data analytics, boosting productivity and competitiveness. Improved ICT infrastructure enhances global connectivity and integration into value chains, essential for growth.

Developing agroindustries transforms agricultural outputs into higher-value products, stimulating industrial growth and rural development. Agricultural innovations, such as precision agriculture through farming and biotechnology, increase productivity and sustainability. A robust agricultural sector ensures food and nutrition security, crucial for a stable industrial workforce.

Focusing on these priority areas helps diversify the economy, reducing dependence on a single sector and promoting balanced industrial growth. Investments in energy, ICT and health infrastructure create a supportive environment for industrial activities as highlighted in SDG9. Enhancing education and healthcare contributes to developing a skilled and healthy workforce, capable of driving industrial innovation and productivity. Aligning R&D with these possible priority areas ensures that industrialisation efforts are sustainable and address critical socio-economic and environmental challenges. Prioritising R&D through its investment in these areas fosters an innovation ecosystem that can lead to new technologies, improved industrial processes and increased competitiveness.

Beyond R&D: Essential Components for Driving Industrialisation

Industrialisation or reindustrialisation programmes in emerging economies implicitly assume the incorporation of technologies or the nurturing of value-added knowledge industries. R&D is therefore an essential component of industrialisation programmes. However, it is not the only ingredient that would result in enhanced competitiveness and overall benefits in well-being.

To provide a more comprehensive analysis of the importance of R&D investment within the context of industrialisation, it is necessary to incorporate insights from modern endogenous growth theory.

A key reference for endogenous growth theory is the work of Paul Romer, who was awarded the Nobel Prize in 2018 for his pioneering research. Romer's theory emphasises that economic growth is driven by internal factors, such as technological innovation and human capital, rather than external forces. Human capital and integration into world markets determine the growth rate. His seminal paper, Endogenous Technological Change (1990), laid the foundation for understanding how R&D investments and innovation drive long-term productivity and economic growth. Romer's work demonstrated how policy measures – such as investment in R&D and human capital – can influence the rate of technological progress, contrasting with earlier neoclassical models that treated technological advancement as an external factor.

Spending by firms on research and development serves as an investment in generating new technological knowledge, which subsequently functions as a production factor that drives economic growth. According to innovation economics, when the knowledge generated through the R&D investment process is utilised as a production factor, its contribution to productivity – and, by extension, to long-term increases in GDP per capita – can be reasonably inferred. The key insight in this framework is that long-term growth is driven by internal factors such as human capital and technological innovation. Intramural R&D is a specialised innovation activity crucial for developing technologies that are indigenous to the regions where enterprises operate. These innovation efforts must be complemented by a workforce that is not only skilled but also possesses indepth knowledge, enabling firms to leverage technology-driven growth. This necessitates a systemic approach, where higher education institutions, such as tertiary institutions and technical schools, play a pivotal role in producing a highly skilled labour force. These institutions are fundamental in cultivating human capital that is proficient in the latest technological advances, which fuels innovation and enhances the competitive advantage of firms within their local context.

As such, industrialisation, beyond a policy of growing R&D intensiveness, requires a skilled workforce and developed institutional capabilities of enterprises. Countries across Africa often have large informal business sectors of micro-enterprises that play a critical role in their economies. We conclude this section with reflections on how innovation activities within this sector could potentially support industrialisation.

The informal sector, traditionally viewed as marginal to the formal economy and mainly absorbing unemployment during economic or political instability, can be reimagined as an important contributor to workforce development and capabilities growth. Accelerated Industrialisation requires not just technical expertise but also strong problem-solving skills and innovative thinking, often cultivated in resource-constrained environments like the informal sector. In South Africa for instance, especially in response to high unemployment, some citizens engage in informal work where they are forced to adapt and innovate in the face of limited resources.

The informal sector, therefore, offers a valuable opportunity to develop entrepreneurial skills, adaptability and resourcefulness – attributes critical for driving industrialisation. Mustapha et al (2021) argue that the informal sector is a dynamic space for entrepreneurship and innovation, shifting the traditional view of it as subordinate to the formal economy. The skills homed in this sector could become essential as South Africa seeks to bolster its workforce for a modern industrial economy. Furthermore, there is an intriguing possibility for mutual learning between the formal and informal sectors. From an innovation systems perspective, linkages between these sectors enable knowledge and skill transfer, creating learning pathways that can strengthen both. While informal workers often gain valuable experience in problem-solving and innovation, formal businesses could benefit by incorporating these adaptive skills into their broader industrial strategies. As Kruss (2021) suggests, harnessing the potential of the informal sector through targeted support and integration could enhance workforce development, ultimately contributing to South Africa's industrialisation efforts. By recognising and strategically linking informal sector activities to national economic strategies, South Africa can augment its skilled workforce and improve the effectiveness of its R&D and innovation initiatives. This approach could drive inclusive economic growth not just within the country, but also across the African continent, where similar dynamics exist.

5.2 METHODOLOGY AND OVERVIEW OF R&D DATA

This section provides descriptions on the methods required for collecting data on research and experimental development (R&D) and its components, including basic or fundamental research, applied research and experimental development. Following these definitions establishes the framework for R&D surveys. R&D surveys are designed to measure R&D activity at the national level or within the country. A common proxy for measuring R&D activities is R&D expenditure. It's important to differentiate between R&D activity, indicated by the aggregate R&D expenditure and R&D investment, which is typically represented by funding for R&D. This distinction is crucial because the government funding, from the source of funds viewpoint, always plays a significant role in many contexts, even though the government itself may conduct minimal R&D, when captured as sector of R&D performance. In contrast, in the business sector – where companies largely fund their own research – the terms R&D activity and R&D investment can often be used interchangeably.

The ASTII national surveys are always conducted in accordance with the international guidelines specified in the Frascati Manual (OECD, 2015)[16] for R&D. The use of the manual affords countries the opportunity to adopt consistent and common standards and methodologies thereby allowing for the comparison of statistics both over time and between different national contexts.

Delineating Research and Experimental Development

The term R&D has expanded to encompass three types of activities.

- **Basic or fundamental research** is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Primarily found in tertiary and public research institutions, this type of R&D focuses on acquiring new knowledge about fundamental principles and theories without immediate practical applications in mind. Tertiary institutions are well-suited for basic research due to their academic freedom, access to specialised expertise and resources aimed at exploring theoretical concepts (OECD, 2015). In addition, government-funded research institutions also contribute significantly to basic research, particularly in fields like physics, biology and social sciences
- **Applied research** is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective. Commonly conducted in both higher education and the business sectors, it is the most common type of research in many countries and solve specific practical problems, including through

16 The definition of R&D in the seventh edition of the Frascati Manual aligns with the definitions used in previous editions and encompasses the same range of activities (OECD, 2015: 45, para. 2.8).

collaboration to address real-world issues. Higher Education institutions may engage in applied research to enhance their academic offerings and support local industries. In the business sector, applied research is integral to product development and improvement, allowing companies to innovate based on market needs (National Science Board, 2020)

- **Experimental development** is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes. (OECD, 2015: 29, para 1.35). This type of R&D is most prevalent in the business sector where knowledge is applied to develop new products and/or processes or improve existing ones. Experimental development typically involves significant investment and collaboration among various departments within a firm (OECD, 2015). While some higher education entities may engage in experimental development through partnerships with firms, it remains predominantly a business-oriented activity focused on commercialisation and practical application (National Science Board, 2020)

5.3 DEFINING R&D IN INSTITUTIONAL SECTORS

The Frascati Manual adheres to the System of National Accounts (SNA) delineation, where "product" refers to either a good or a service. Additionally, within the manual, "process" refers to the transformation of inputs into outputs, as well as their delivery or to organisational structures and practices (OECD, 2015: 29, para 1.35).

> A domestic indicator refers to a statistical measure that provides insights into the economic, social or environmental conditions within a country's borders

According to the Frascati Manual, GERD "is total intramural expenditure on R&D performed in the national territory during a specific reference period" (OECD, 2015: 111, para 4.7). It is defined as a domestic indicator to allow for comparability with GDP and other domestic economic indicators. Intramural R&D expenditures encompass all current expenditures plus gross fixed capital expenditures for R&D performed within a statistical unit during a specific reference period, irrespective of the source of funds (OECD, 2015: 112, para 4.10). Current expenditures consist of labour costs for R&D personnel and other ongoing expenses associated with conducting R&D activities, including infra-annual equipment costs and rent on assets (OECD, 2015: 113, para 4.15). These concepts extend into institutional sector categories, defined as follows:

- **Business Enterprise Expenditure on R&D** (BERD) measures intramural R&D expenditures within the business sector during a specified reference period (OECD, 2015: 208, para 7.35)
- **Government Expenditure on R&D** (GOVERD) measures intramural R&D expenditures within the government sector during a specified reference period (OECD, 2015: 243, para 8.36)
- **Higher Education Expenditure on R&D** (HERD) measures intramural R&D expenditures in the higher education sector during a specified reference period (OECD, 2015: 269, para 9.53)
- **Private Non-Profit Expenditure on R&D** (PNPERD) measures intramural R&D expenditures within the Private Non-Profit sector during a specified reference period (OECD, 2015: 292, para 10.21)

In the discourse surrounding Science, Technology and Innovation (STI) measurement, the terms **GERD** and **BERD** are widely recognised and commonly used. In contrast, other related abbreviations are not as frequently encountered or utilised in discussions. This distinction highlights the prominence of GERD and BERD in the context of R&D measurement and policy analysis within various academic and governmental frameworks. Because GERD is a domestic indicator, the collection of R&D expenditure from enterprises that reside outside the territory of the country do not form part of the compilation of R&D expenditures in any of the sectors. Subsidiaries of foreign firms that perform R&D within the country territory are included[17] for being registered locally to legally operate.

17 Note that funds received from enterprise group members of a multinational subsidiary who reside outside the country are categorised as foreign funding of the subsidiary.

Degrees of Reporting Statistics

R&D projects can be considered a collection of R&D activities aimed at achieving a specific objective (OECD, 2015: 46, para 2.12). R&D projects are organised within enterprises across any of the four institutional sectors or in borderline cases where enterprises in different sectors may enter joint ventures. In the business sector, data on R&D projects is collected at the enterprise level or from components of the enterprise and sometimes from groups of enterprises, depending on data availability. The Frascati Methodology is not well-suited to collect data at the project level.

Due to practical challenges associated with the diverse organisational structures and reporting practices of complex enterprises, compiling statistical units that break down enterprises at the geographical level proves to be difficult. For example, universities may choose to report their statistics at the level of individual faculties or jointly compiled at the level of the university. This diversity in enterprise organisation can lead to inconsistencies in how data is reported and categorised, making it challenging to create uniform statistical measures across different regions. Consequently, this hampers efforts to accurately assess and compare R&D activities within various geographical contexts. Several studies highlight these issues in statistical reporting and disaggregation. For example, the OECD (2015) discusses the complexities in collecting data from multinational enterprises due to varying accounting practices and regulatory environments across countries.

R&D projects can be considered a collection of R&D activities aimed at achieving a specific objective (OECD, 2015: 46, para 2.12).

All the same, typically, all countries can publish data at the enterprise level.

The data collection focused on measurement within four broad sectors, three of which align with the Systems of National Accounts (SNA) institutional classification: Business, Government and Private Non-Profit. Higher education is unique to the R&D statistical framework, in contrast to the System of National Accounts framework. It is defined based on user needs and overlaps with the others (OECD, 2015: 97, para 3.50).

R&D **funding sources** include business enterprises, government institutions, higher education institutions, private non-profit organisations and bodies in the rest of the world. Funding from the rest of the world includes international organisations, defined to encompass supranational organisations (OECD, 2015: 132), such as the African Union (AU).

Statistics on **R&D personnel** are collected in headcount numbers, Full-time equivalents and their characteristics (OECD, 2015: 165, para 5.46), “notably by sex, function, employment status, age and formal qualification, but also by seniority level, geographic origin and personnel flows (OECD, 2015: 172, para 5.75)”. Full-time equivalent (FTE) of R&D personnel is defined as the ratio of the actual hours spent on R&D activities during a specific reference period (typically a calendar year) to the total number of hours conventionally worked in that same period by an individual or a group (OECD, 2015: 166, para 5.49).

Finally, R&D within enterprises in all institutional sectors may usefully be classified according to how they distribute their R&D resources across projects according to the knowledge domain or **research fields**, in which they operate (OECD, 2015: 57, para 2.42) and according to the **socio-economic objectives** to which they are oriented. Research field classification standards are primarily based on the International Standard Classification of Education (ISCED) and the Classification of Functions of Government (COFOG). This classification system organises research activities into various fields, allowing for consistent reporting and comparison of R&D data across different countries and sectors. Similarly, the Frascati Manual employs a classification standard for socio-economic objectives that is aligned with the OECD’s Classification of Research and Development (R&D) Activities. This framework categorises R&D according to its intended socio-economic objectives, allowing for systematic analysis and comparison of research activities across different countries and sectors.

5.4 AFRICAN COUNTRY R&D SURVEYS

The R&D data presented herein includes R&D expenditure (including funding sources) and R&D personnel. The R&D surveys collected data on expenditures and personnel from ten countries (Table 5.1a) for AIO-4. Only five provided data for the most recent reference year, 2022 and two countries provided data for 2021. Three countries last submitted data for 2019, while the remaining countries had not submitted any data by the time of writing. Of the ten countries that submitted data, only six fully covered the four sectors mentioned. Exercise caution when making comparisons between these countries, as they have not all employed the same survey methodologies.

This sparsity of data submission is a persistent trend in AIO data collections. The R&D survey data from the 2019 African Innovation Outlook III (AIO-2019) covered only the years 2012 to 2015. Among the 23 states that contributed data, only eight had submitted information for the AIO series since 2010, highlighting a lack of consistent participation. Furthermore, the coverage of R&D surveys was largely incomplete, primarily focusing on public sector performers such as universities, government entities and public research institutes (AIO, 2019; Kahn, 2022). This limited scope restricts the comprehensive understanding of R&D activities across the region.

Methodology of Purchase Power Parity (International Dollar) – PPP$

Purchasing power parities (PPPs) are the rates of currency conversion that try to equalise the purchasing power of different currencies, by eliminating the differences in price levels between countries. The basket of goods and services priced is a sample of all those that are part of final expenditures: final consumption of households and government, fixed capital formation and net exports. This indicator is measured in terms of national currency per US dollar. (https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm). To convert socio-economic indicators from Local Currency Unit (LCU) to PPP requires the division of the amount in LCU of a specific year by the Implied PPP conversion factor (also called National currency per current international dollar) of the same year. For instance, Benin had in 2022 (reference period of the R&D survey) a GDP in million LCU estimated to 10,854,508 with an implied PPP conversion factor of 200.3. Thus, GDP in PPP$ Million (current international dollar – millions) will be 10,838,191 divided by 200.55 or $54,04 Million in PPP. Those figures are from the **World Economic Outlook** (IMF, 2023)[18] with 2015 as base year.

18 International Monetary Fund, World Economic Outlook Database, April 2023 https://www.imf.org/en/Publications/WEO/weo-database/2023/April/weo-report?c=638,&s=NGDP,PPPEX,&sy=2021&ey=2023&ssm=0&scsm=1&scc=0&ssd=1&ssc=0&sic=0&sort=country&ds=.&br=1

Table 5.1a Characteristics of AIO – datasets submitted from R&D surveys in 12 countries

Serial No	Country	Reference Year*	Business		Government		Higher Education		Private Non-Profit	
			R&D Personnel	R&D Expenditure	R&D Personnel	R&D Expenditure	R&D Personnel	R&D Expenditure	R&D Personnel	R&D Expenditure
1	Benin – NEW	2022	-	-	✓	✓	✓	✓	-	-
2	Egypt	2022	✓	✓	✓	✓	✓	✓	✓	✓
3	Ghana	2022	✓	✓	✓	✓	-	-	-	-
4	Malawi	2019	✓	✓	✓	✓	✓	✓	✓	✓
5	Mali	2021	✓	✓	✓	✓	✓	✓	✓	✓
6	Mauritius	2022	✓	✓	✓	✓	✓	✓	✓	✓
7	Namibia	2022	✓	-	✓	-	✓	-	✓	-
8	Nigeria	2019	-	-	✓	✓	✓	✓	-	-
9	Rwanda	2023	✓	✓	✓	✓	✓	✓	✓	✓
10	Senegal	2022	-	-	-	-	✓	-	-	-
11	South Africa	2021	✓	✓	✓	✓	✓	✓	✓	✓
12	Zambia	2022	-	-	✓	✓	✓	✓	-	-
	Total		**8**	**7**	**11**	**10**	**11**	**9**	**7**	**6**

The financial and reference years have been the same however both financial year 2021/22 and 2022/23 will be written 2021 and 2022 then they are expressed in reference years.

All data presented in this report were collected by the participating African countries, except for population data [(1) United Nations Population Division. World Population Prospects: 2022 Revision. (2) Census reports and other statistical publications from national statistical offices, (3) Eurostat: Demographic Statistics, (4) United Nations Statistical Division. Population and Vital Statistics Report (various years), (5) US Census Bureau: International Database and (6) Secretariat of the Pacific Community: Statistics and Demography Programme] and respective GDP figures, which were obtained from World Bank national accounts data and OECD National Accounts data files. Purchasing power parity (PPP$) was used to convert various currencies into a common currency using data from the International Comparison Programme of the World Bank, sourced from the World Development Indicators database, World Bank | Eurostat-OECD PPP Programme.

5.5 R&D PERSONNEL

This section provides data on R&D personnel by country and R&D characteristics. Information on R&D personnel was submitted by (12 countries) Benin, Egypt, Ghana, Malawi, Mali, Mauritius, Namibia, Nigeria, Senegal, South Africa (Republic), Rwanda and Zambia. R&D personnel plays a major role in undertaking various R&D activities that determine the overall success of the processes involved in the production of Science Technology and Innovation Indicators (STII) that are key in policy formulation and decision-making for socio-economic development of any country. R&D personnel that are directly involved in R&D activities are internal or external based in a statistical unit performing R&D. They are full-time or part-time and are categorised according to their function namely researchers, technicians and other support staff. The measurement of R&D personnel is undertaken in the four main sectors namely, Business Enterprises, Government, Higher Education and, Private Non-Profit. The characteristics of R&D personnel include sex, age, occupation, formal qualification, Full-time equivalent and field of R&D (OECD, 2015: 151, para 5.6).

5.5.1 Categories of R&D Personnel

R&D personnel are presented in Headcount and Full-Time Equivalence in four categories namely: **Total R&D personnel, Female R&D personnel, Researchers and Female researchers.** This categorisation shows clearly the representation of each cadre in the four sectors.

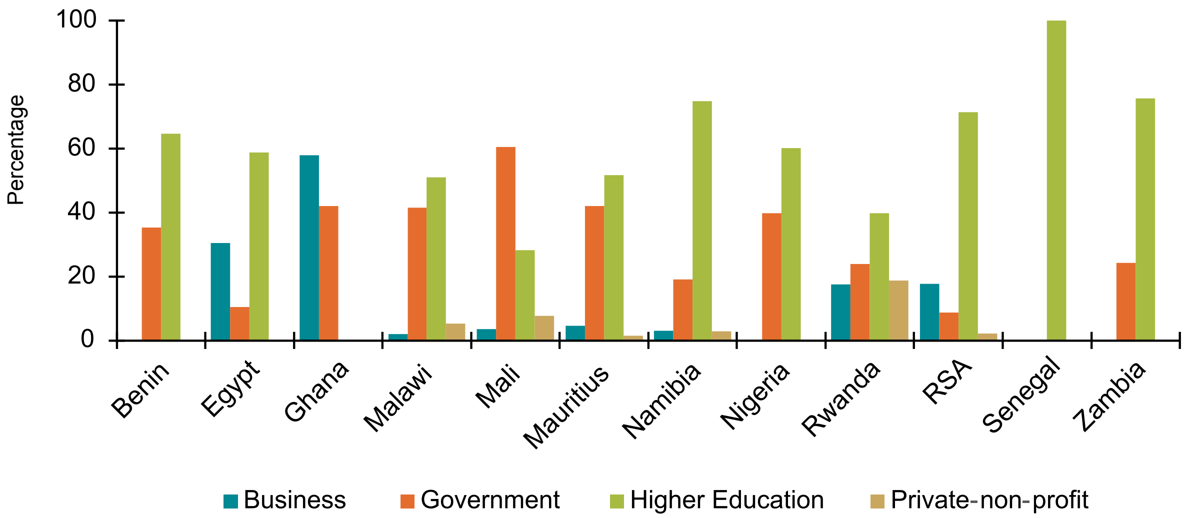
Table 5.1b R&D personnel by sector, headcount (HC)

Area Surveyed	Country	R&D personnel	Business	Government	Higher Education	Private non-profit
BUS/GOV/ HE/PNP	Egypt	343 198	30.4%	10.5%	58.9%	0.2%
	Malawi	2 829	2.1%	41.6%	51.0%	5.4%
	Mali	2 009	3.6%	60.5%	28.2%	7.7%
	Mauritius	3 008	4.7%	42.1%	51.7%	1.5%
	Namibia	3 439	3.0%	19.2%	74.9%	2.9%
	Rwanda	7 411	17.5%	24.0%	39.8%	18.8%
	RSA	100	17.6%	8.8%	71.4%	2.2%
GOV/HE	Benin	100	NA	35.3%	64.7%	NA
	Nigeria	41 431	NA	39.8%	60.2%	NA
	Zambia	3 429	NA	24.2%	75.8%	NA
BUS/GOV	Ghana	3 914	57.9%	42.1%	NA	NA
HE	Senegal	26 390	NA	NA-	100.0	NA

Note: Senegal with only one sector covered

The distribution of R&D personnel by sector is represented in Table 5.1b and Figure 5.1 Six countries (Egypt, Malawi, Mali, Mauritius, Rwanda and Republic of South Africa) covered all the four sectors whereas four countries; Benin, Nigeria and Zambia covered two sectors namely Government and Higher Education while Ghana covered Business and Government sectors.

Figure 5.1 Distribution of R&D personnel (%) by sector



Egypt recorded the highest number of the total R&D personnel recording 343,198, followed by Republic of South Africa with 85,601. The data further revealed that, Government and Higher Education sectors had a high concentration of R&D personnel. Egypt still registered the highest number of R&D personnel with a proportion of 10.5% and 58.9% of total R&D personnel in government and higher education respectively.

Table 5.2 R&D personnel by sector and occupation

Area Surveyed	Country	Total R&D Personnel	Researchers	Technicians	Support Staff
BUS/GOV/HE/PNP	Egypt	343 198	59.49	25.25	15.26
	Malawi	2 829	44.40	21.17	34.43
	Mali	2 009	38.63	37.43	23.94
	Mauritius	3 008	52.46	18.42	29.12
	Namibia	3 439	72.75	8.00	19.25
	Rwanda	7 411	51.34	29.43	19.23
	RSA	85 601	73.74	11.94	14.32
GOV/HE	Benin	100	59.94	18.47	21.59
	Nigeria	41 431	50.40	26.98	22.62
	Zambia	3 429	73.81	12.54	13.65
BUS/GOV	Ghana	3 414	27.62	42.39	29.99
HE	Senegal	26 390	94.54	2.16	3.29

The Republic of South Africa followed with 9% and 71% of total R&D personnel in the two sectors respectively. The proportions of R&D personnel registered by other countries were: Nigeria (40%, 60%) Mauritius (42%, 52%), Malawi (42%, 51%), Ghana (42%), Benin (35%, 65%), Rwanda (27%, 48), Mali (60%, 28%) and Zambia (24%, 76%). Ghana recorded the highest proportion of R&D personnel at 58% in the Business sector followed by Egypt at 30%, Rwanda at 17% while Mauritius, Mali and Malawi recorded 5%, 4% and 2% respectively. All the countries registered low proportions of R&D personnel in the Private Non-Profit sector.

Figure 5.2 Distribution of R&D personnel (%) by occupation

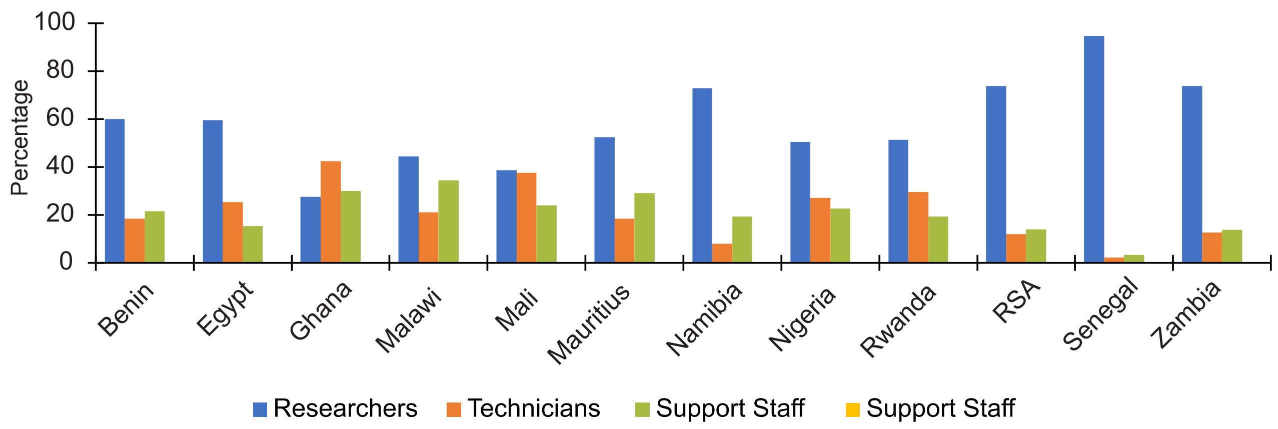
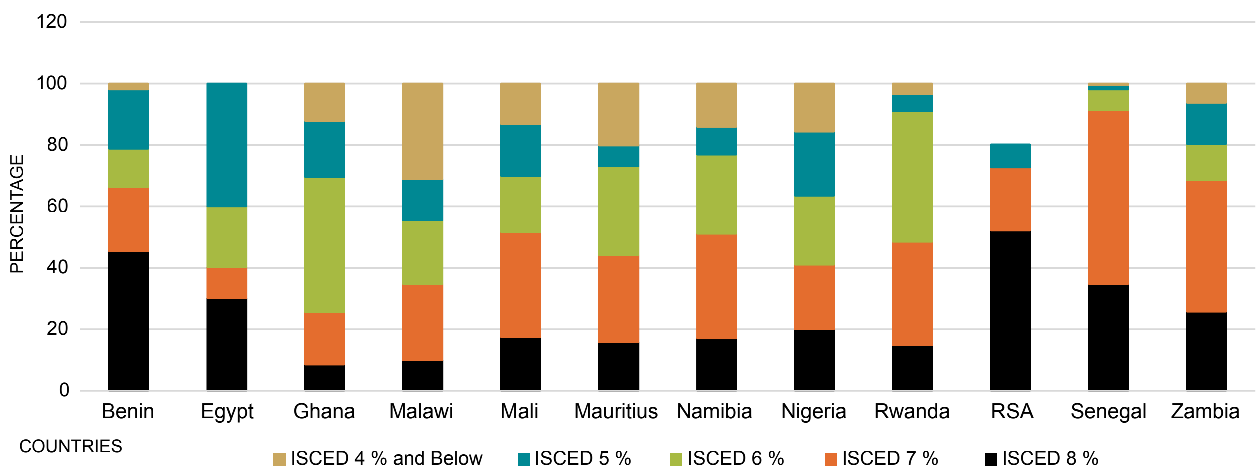


Table 5.2 and **Figure 5.2** present data on the distribution of R&D personnel by function for the ten countries. All countries reported a high concentration of researchers compared to other cadres except Ghana where the proportion of technicians was 42% compared to 28% for researchers. Egypt recorded the highest number of researchers at 204,179 which was 59.5% of total R&D personnel. Republic of South Africa followed with 63,122 at 74% while Nigeria reported 20,881 researchers at 50% of the total R&D personnel. The rest of the countries registered less than three thousand researchers. The data further reveals that all countries reported more technicians than support staff except Malawi, Mauritius and Zambia where support staff were more than technicians. It is also noted that, in Mali, the proportion of researchers and technicians was almost the same. All these cadres play key roles in the production process of developing STI indicators for sustainable development of the African continent.

Figure 5.3 Percentage distribution of R&D personnel by qualification and country



South Africa had the highest number of R&D personnel with PhD or equivalent degree (ISCED 8)[19] at 53%. This was the highest number of PhD holders than any country as shown in Figure 5.3. Benin followed with 45% of its R&D personnel holding the same degree. Meanwhile, South Africa had no R&D personnel with ISCED 6 and ISCED 4 and below qualifications. Egypt had no R&D personnel with ISCED 4 and below qualification while Benin and Zambia had the least of R&D personnel with ISCED 4 and below at 2% and 6% respectively. Egypt and Nigeria had 30% and 20% of R&D personnel with ISCED 8 respectively. Zambia had the most R&D personnel with a Master's degree or equivalent at 43% followed by Rwanda at 39%. Ghana had the largest number of R&D personnel with a Bachelor's degree or equivalent at 44% and together with Malawi had the least number of R&D personnel with a PhD degree qualification. The numbers reported differed across countries. This is particularly the case when students were included as R&D personnel. The differences may had emerged not only from the interpretation of the Frascati Manual (FM) but from the structure of the education system of each country.

19 ISCED: International Standard Classification of Education (ISCED): A reference classification for organising education programmes and related qualifications by education levels and fields (UNESCO, 2011).

Table 5.3 R&D personnel by ffeld of R&D, HC

Sector	Country	Total	Natural sciences	Engineering & technology	Medical sciences	Agricultural sciences	Social sciences	Humanities	Classified elsewhere	Not classified
BUS GOV HE PNP	Egypt	343,198	16.22	18.96	26.91	10.92	18.55	8.45	-	
	Malawi	2,829	8.62	10.00	19.12	19.30	13.61	3.32	-	26.02
	Mali	2,009	6.37	8.81	1.84	49.63	17.12	9.26	-	6.97
	Mauritius	3,008	17.09	15.03	6.91	18.18	15.79	13.46	-	13.53
	Namibia	3,439	15.30	7.15	11.34	6.80	23.52	1.98	31.06	2.85
	Rwanda	7,411	12.83	21.13	22.35	10.07	22.88	5.96	-	4.78
	RSA	85,601	28.71	7.47	23.17	6.31	28.95	5.40	-	-
GOV HE	Benin	1,348	7.57	5.42	3.86	42.73	6.08	6.75	-	27.60
	Nigeria	41,341	13.78	10.12	12.15	15.92	13.13	7.25	-	27.65
	Zambia	3,429	15.81	9.16	23.51	23.24	20.50	7.70	-	0.09
BUS GOV	Ghana	3,914	10.94	23.25	18.96	16.33	8.79	8.33	-	13.41
HE	Senegal	26,390	21.52	3.85	15.06	2.96	35.02	20.66	0.94	-

Details of R&D personnel by field of R&D are represented in **Table 5.3** for the 10 countries. Rwanda did not analyse data in this area. Egypt had the highest number of R&D personnel in all fields of R&D recording 92 346 in medical sciences, 65 057 in engineering and technology and 63 677 in social sciences. Republic of South Africa followed with 24 782 in social sciences, 24 580 in natural sciences and 19 830 in medical sciences. The results further show almost even distribution of R&D personnel in all the fields of R&D for Nigeria. The rest of the countries had quite a reasonable distribution of R&D personnel in each of the field of R&D.

Table 5.4 shows the distribution of R&D personnel by age. Age is one of the key variables attributed to information on population in general. This is because, age is one of the defining factors that play a key role in progression and sustainability of any organisation in determining youthful, middle or aging personnel. It is therefore an indicator that is to be monitored regularly to avoid any vacuum that might be created within sectors that perform R&D activities. About half of the countries did not have data on age. For countries that reported data on age, Benin, Ghana, Nigeria and Zambia had the largest cohort of R&D personnel in the age group 35-44 years while the highest for Mali was between 45 and 54 years. Mali and Zambia had the least number of R&D personnel under 25 years and Benin and Ghana had fewer R&D personnel at the age of 65 years and over. The first and second AIO reports (AIO-2010 and AIO-2014) did not have information on R&D personnel by sector of performance and age to identify any trends despite the provision in both the standard R&D questionnaires and the R&D reporting templates.

Table 5.4 R&D personnel by age, HC

Coverage	Country	Total R&D personnel	Under 25	25-34	35-44	45-54	55-64	65 and over	Not classified
BUS/GOV/ HE/PNP	Egypt	343,198							
	Mali	2 009	1	309	499	787	377	36	
	Namibia	3 439	66	676	1100	683	362	48	504
	Mauritius	3 008	65	644	990	796	392	11	110
	Malawi	2 829							
	South Africa	85 601							
	Rwanda	7 411	460	2 798	2 657	1 095	365	36	
GOV/HE	Benin	1 348							
	Nigeria	41 341	4 879	5 909	11 910	10 094	4 767	3 872	
	Zambia	3 429	12	381	1 148	1 109	644	135	
BUS/GOV	Ghana	3 914	101	1 214	1 570	779	232	8	10
HE	Senegal	26 390	428	9 898	7 405	6 182	2 165	312	

Table 5.5 R&D personnel by sector and function, HC

Area surveyed	Country	R&D Per-sonnel	Business			Government			Higher Education			Private Non-Profit		
			Researchers	Technicians	Support staff	Researchers	Technicians	Support staff	Researchers	Technicians	Support staff	Researchers	Technicians	Support staff
All (BUS/ GOV/ HE/PNP)	Egypt	343 198	48 391	37 065	18 876	23 681	5 491	6 864	131 788	43 929	26 426	343	343	1
	Malawi	2 829	42	0	17	187	286	702	1 007	215	224	23	96	30
	Mali	2 009	30	36	6	348	496	372	368	159	40	30	60	64
	Mauritius	3 008	39	69	33	526	289	451	999	171	388	15	27	1
	Namibia	3 439	58	20	24	595	45	21	1 799	193	585	48	21	30
	Rwanda	7 411	459	156	660	919	674	378	2 579	600	378	230	215	163
	Senegal	26 930	-	-	-	-	-	-	25 449	592	889	-	-	-
	RSA	85 601	4 366	5 307	5 393	3 510	2 140	1 798	5 4785	2 054	4 366	428	685	769
GOV/HE	Benin	1 348	-	-	-	121	115	241	688	135	48	-	-	-
	Nigeria	41 431	-	-	-	6 214	5 510	4765	14 667	5 676	4 599	-	-	-
	Zambia	3 429	-	-	-	322	233	274	2 208	199	193	-	-	-
BUS/GOV	Ghana	3 914	493	971	802	587	689	372	-	-	-	-	-	-

Table 5.6 Percentage distribution of R&D personnel by sector and occupation, HC

Area surveyed	Country	R&D Per-sonnel	Business			Government			Higher Education			Private Non-Profit		
			Researchers	Technicians	Support staff	Researchers	Technicians	Support staff	Researchers	Technicians	Support staff	Researchers	Technicians	Support staff
All (BUS/ GOV/ HE/PNP)	Egypt	343 198	14.1	10.8	5.5	6.9	1.6	2	38.4	12.8	7.7	0.1	0.1	0.1
	Malawi	2 829	1.5	0	0.6	6.6	10.1	24.8	35.6	7.6	7.9	0.8	3.4	1.2
	Mali	2 009	1.5	1.8	0.3	17.3	24.7	18.5	18.3	7.9	2	1.5	3	3.2
	Mauritius	3 008	1.3	2.3	1.1	17.5	9.6	15	33.2	5.7	12.9	0.5	0.9	0.2
	Namibia	3 439	1.7	0.6	0.7	17.3	1.3	0.6	52.3	5.6	17	1.4	0.6	0.9
	Rwanda	7 411	6.2	2.1	8.9	12.4	9.1	5.1	34.8	8.1	5.1	3.1	2.9	2.2
	Senegal	26 930	-	-	-	-	-	-	94.5	2.2	3.3	-	-	-
	RSA	85 601	5.1	6.2	6.3	4.1	2.5	2.1	64	2.4	5.1	0.5	0.8	0.8
GOV/HE	Benin	1 348	-	-	-	9	8.5	17.9	51	10	3.7	-	-	-
	Nigeria	41 431	-	-	-	15	13.3	11.5	35.4	13.7	11.1	-	-	-
	Zambia	3 429	-	-	-	9.4	6.8	8	64.4	5.8	5.6	-	-	-
BUS/GOV	Ghana	3 914	12.6	24.8	20.5	15	17.6	9.5	-	-	-	-	-	-

The distribution of R&D personnel by occupation and sector of employment is presented in **Tables 5.5** and **5.6.** All the ten countries reported a high concentration of R&D personnel in both Government and Higher Education sectors with Egypt recording the highest number of personnel in almost all the sectors. Furthermore, the proportion of researchers in most countries was also higher than other cadres. In the Business sector, Egypt and Ghana reported a high proportion of researchers at 14.1% and 12.6% respectively. All the countries reported a high proportion of researchers compared to technicians in the Government sector except, Malawi, Mali and Ghana that reported a slightly low proportion of researchers at 6.6%, 17.3% and 15.0% respectively. In the Higher education sector, the proportion of researchers was higher compared to other cadres for all countries except Ghana where the data was not available for this sector. For the Private Non-Profit sector, Republic of South Africa, Egypt and Rwanda reported a high number of researchers at 444,364 and 106 respectively compared to other cadres while Benin, Ghana, Nigeria and Zambia did not collect data in this sector.

Full-time equivalent (FTE)

Full-time equivalent (FTE) measures the total amount of time of full-time employees working at any given organisation. It is derived by adding up the hours of full-time, part-time and various other types of employees into measurable 'full-time' units.

Table 5.7 Full-time equivalent of R&D personnel

Area surveyed	Country	Total FTE	Business	Government	Higher Education	Private Non-Profit
BUS/GOV/ HE/PNP	Egypt	259 175.3	125 690.1	34 824.5	97 903.9	756.9
	Malawi	1 655.7	16.5	1 090.2	495.9	53.1
	Mali	1 645.7	27.0	1 006.6	458.6	153.5
	Mauritius	1 676.7	67.0	894.9	678.6	36.2
	Namibia	887.2	66.2	78.2	677.2	65.6
	Rwanda	3 655.1	667.6	891.7	1 343.4	752.4
	RSA	44 355.4	12 054.6	5 934.0	24 789.8	1 577.1
GOV/HE	Benin	980.8	-	573.7	407.1	-
	Nigeria	6 260.7	-	3 779.3	2 481.4	-
	Zambia	1 488.2	-	746.6	741.6	-
BUS/GOV	Ghana	3 053.8	1 771.7	1 282.1	-	-
HE	Senegal	5 584.0	-	-	5 584.0	-

Details of Full-time equivalent for R&D personnel by sector are presented in **Table 5.7.** Egypt recorded the highest FTE for all R&D personnel at 249 175.3 followed by Republic of South Africa, Nigeria and Ghana at 44 355.4, 41 431.0 and 3 053.8 respectively. In business sector, still Egypt led followed by Republic of South Africa and Ghana recording 125 690.1, 12 054.6 and 1 771.7 respectively. Benin, Nigeria and Zambia did not collect data in this sector. As for the Government sector, Egypt still led followed by Nigeria, Republic of South Africa and Ghana at 34 824.5, 16 470.0, 5 934.0 and 1 282.1 respectively. In higher education sector, Egypt, Nigeria and Republic of South Africa continued to record high FTE at 97 903.9, 24 961.0 and 24 789.8. Six countries, Egypt, Malawi, Mali, Mauritius, Rwanda and Republic of South Africa reported low FTE in Private Non-Profit sector compared to Government and Higher Education sectors. Malawi and Mali are the only countries that reported low FTE for R&D personnel in business sector compared to Private Non-Profit sector. Benin, Nigeria, Zambia and Ghana did not collect data in Private Non-Profit sector.

Researchers

Researchers are professionals who conduct research and improve or develop concepts, theories, models techniques and software of operational methods. They are involved in fully or partially in different types of activities in any sector of the economy as well as identify options for new R&D activities, plan and manage them by using high-level skills and knowledge in performing research.

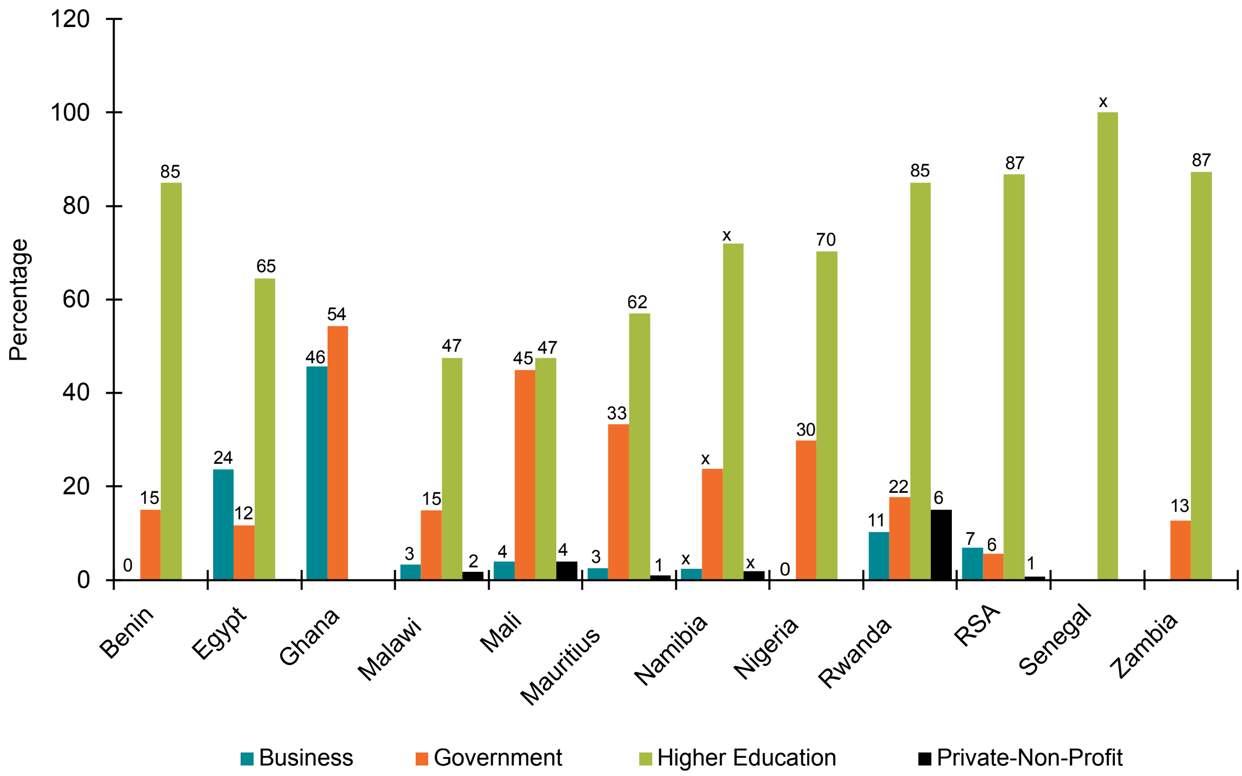
Researchers take the lead in R&D projects and therefore play an essential role in R&D activities. They are assisted by other R&D personnel who undertake key roles in different components of a project.

Table 5.8 Researchers by sector (HC)

Area surveyed	Country	Total researchers	Business	Government	Higher Education	Private Non-Profit
BUS/GOV/ HE/PNP	Egypt	204 179	23.64	11.65	64.53	0.18
	Malawi	1 256	3.26	14.89	80.10	1.75
	Mali	776	3.87	44.85	47.42	3.87
	Mauritius	1 578	2.53	33.27	63.24	0.95
	Namibia	2 502	2.40	23.78	71.94	1.88
	Rwanda	3 805	10.28	17.77	56.98	14.98
	RSA	63 122	6.92	5.58	86.79	0.70
GOV/HE	Benin					
	Nigeria					
	Zambia					
BUS/GOV	Ghana	1 081	45.70	54.30	-	-
HE	Senegal	24 950			100	

The development in any sector of the economy depends on human resources and especially researchers with knowledge and skills, as well as new ideas and means of identifying gaps that may hinder economic and social progress. Researchers play a crucial role through their collective effort to ensure the processes involved in research are optimally exploited to achieve the best results. **Table 5.8** gives details of researchers by sector in ten countries that submitted data with Egypt reporting the highest number of researchers at 204 179 followed by Republic of South Africa at 63 122 and Nigeria with 20 881. The rest of the countries reported as follows; Zambia 2 531, Rwanda 1 924, Mauritius 1 578, Malawi 1 256, Ghana 1 081, Benin 808 and Mali 776.

Figure 5.4 Researchers by sector (%)



Furthermore, Egypt still recorded the highest number of researchers in the Business sector at 48 278, followed by the Republic of South Africa at 4 370, Ghana and Rwanda with 494 and 210 respectively. The rest of the countries except Nigeria, Zambia and Benin which did not cover the sector, recorded their FTE value below a hundred. All 10 countries showed a high concentration of researchers in Higher Education and Government sectors. The high concentration of researchers in the Higher Education and Government sectors could be attributed to the commitment and direct linkage to financing authorities to these sectors for sustainability. Details of the proportion of researchers in all the sectors for the ten countries are also shown in **Figure 5.4**.

Table 5.9 Researchers by qualification, HC

Coverage	Country	Total researchers	ISCED 8	ISCED 7	ISCED 6	ISCED 5	ISCED 4 and below
All (BUS/ GOV/ HE/PNP)	Namibia	2 502	22.46	41.21	19.50	5.68	11.15
	RSA	63 122	70.28	25.74	2.11	1.88	-
	Rwanda	3 805	27.83	48.99	21.08	1.18	0.92
GOV/HE	Benin	808	74.13	22.28	3.22	0.37	-
	Nigeria	20 881	38.63	32.34	19.27	4.25	5.51
	Zambia	2 531	34.33	55.47	9.72	0.47	-
BUS/GOV	Ghana	1 081	28.49	40.24	22.66	6.94	1.67
HE	Senegal	24 950	35.14	57.71	6.30	0.85	-

Table 5.10 Researchers by field of R&D, HC

Coverage	Country	Total	Natural sciences	Engineering and technology	Medical sciences	Agricultural sciences	Social sciences	Humanities	Classified elsewhere	Not classified
All (BUS/GOV /HE/PNP)	Egypt	173 089	15.23	17.05	29.15	11.11	18.20	9.26	-	-
	Malawi	1 256	12.66	16.00	22.93	10.35	23.57	5.02		9.47
	Mali	746	6.03	17.56	1.21	32.98	25.20	14.21		2.82
	Mauritius	1 578	17.81	20.15	4.25	9.82	25.22	20.03		2.72
	Namibia	2 502	15.15	7.47	12.59	7.11	27.18	2.44	4.36	23.70
	Rwanda	3 805	12.93	21.29	22.84	10.04	24.26	6.68	-	1.97
	RSA	63 122	28.74	7.09	17.70	5.26	34.57	6.64	-	-
GOV/HE	Benin	808	10.89	6.68	5.69	25.25	9.78	11.26	-	30.45
	Nigeria	20 881	17.75	11.47	15.09	12.59	14.87	7.81	-	20.43
	Zambia	2 531	17.50	9.48	25.21	15.17	22.84	9.80	-	-
BUS/GOV	Ghana	1 081	16.65	20.07	11.38	26.55	10.27	8.88	-	6.20
HE	Senegal	24 950								

Egypt, South Africa and Nigeria in that order, led in the number of researchers in all fields of R&D as shown in **Table 5.10.** The number of researchers by field of R&D differ from country to country. However, most of the countries had a strong presence of researchers in the social science field. The number of researchers in the social sciences surpassed the number of researchers in the Engineering and Technology fields in the three countries mentioned above. The highest number of researchers in all countries combined were in the medical sciences (75 545) with 78.8% of them based in Egypt. Within Egypt, the researchers in the medical sciences amounted to 29.1% of all researchers by field of R&D. Mali had the least share of researchers in the medical sciences. However, the number of researchers that were not classified in the countries should be taken into considerations to find out exactly where they belong.

Table 5.11 Researchers by age, HC

Coverage	Country	Age of researchers	Under 25	25-34	35-44	45-54	55-64	≥65	Not classified
All (BUS,GOV. HE,PNP)	Mali	776	-	2.45	18.81	51.68	25.13	1.93	-
	Mauritius	1 578	2.79	23.76	33.40	24.52	12.36	0.70	2.47
	Namibia	2 502	1.80	15.83	30.02	19.02	11.67	1.88	19.78
	Rwanda	3 805	3.29	25.31	40.79	22.50	7.52	0.60	-
GOV/HE	Benin	808	1.24	20.54	36.76	25.87	13.37	2.23	-
	Nigeria	20 881	0.94	12.92	27.46	25.30	13.04	3.52	16.82
	Zambia	2 531	0.32	8.18	31.88	33.47	21.14	5.02	-
BUS/GOV	Ghana	1 081	2.96	21.46	45.88	22.02	6.85	0.83	-
HE	Senegal	24 950	1.43	37.95	27.85	23.15	8.38	1.25	-

Table 5.12 Full-time equivalent (FTE) for researchers by sector

Area surveyed	Country	Total FTE	Business	Government	Higher Education	Private Non-Profit
All (BUS/ GOV/HE/ PNP)	Egypt	92 666.0	20 998.7	22 620.5	48 715.6	331.2
	Malawi	474.5	11.0	161.7	286.3	15.5
	Mali	632.1	12.6	299.0	290.5	30.0
	Mauritius	739.2	29.9	262.3	438.3	8.7
	Namibia	641.0	43.9	50.9	504.2	42.0
	Rwanda	1 837.4	215.2	384.6	922.9	314.7
	RSA	27 763.2	2 927.7	2 624.6	21 861.5	349.4
GOV/HE	Benin	446.0	-	91.7	354.3	-
	Nigeria	4 583.9	-	2 237.4	2 346.5	-
	Zambia	940.8	-	316.3	624.5	-
BUS/GOV	Ghana	741.1	326.6	414.5	-	-
HE	Senegal	4 939.0	-	-	4 939.0	-

FTE in this context refers to a unit of measurement used to find out the number of full-time hours worked by researchers in a specific sector. **Table 5.12** gives details of FTE for researchers by sector. Egypt recorded the highest FTE for researchers at 92 666.0 followed by the Republic of South Africa at 27 763.2 and Nigeria at 4 583.9. The rest of the countries registered their total FTE for researchers below 1 000.0. Looking across the sectors, the Government and Higher Education maintained a high concentration of Full-time equivalent for researchers compared to the Business and Private Non-Profit sectors. Egypt still registered the highest FTE for researchers in the Government and Higher Education sectors (22 620.5, 48 715.5) followed by the Republic of South Africa (2 624.6, 21 861.5) while Nigeria recorded 2 237.4 and 2 346.5 in the two sectors respectively. Benin registered the lowest FTE for researchers in government with 91.7 while Malawi registered the lowest FTE for researchers in higher education with 286.5. Ghana did not collect data in education and Private Non-Profit sectors.

5.5.2 R&D Personnel and Researchers per Million Inhabitants

R&D personnel and researchers per a million inhabitants is the number of R&D Personnel and Researchers engaged in R&D activities, expressed as per a million inhabitants.

Among the countries that covered the four R&D sectors of performance, only Egypt (1 840), Mauritius (1 250) and South Africa (1 054) are having more than one thousand researchers per million population (SDG 9.5.2) in Table 5.13. Senegal with its 1 441 researchers per a million population can be misleading because the country did not cover the four sectors of R&D performance, namely: Business, Government, Higher Education and Private/Non-Profit organisation.

Table 5.13 R&D personnel and researchers per million inhabitants, HC

Country	Population in millions	R&D personnel	Researchers	Researchers as % of R&D personnel	R&D personnel per million population	Researchers per million population
Benin	13 352 864	1 348	808	59.9	101	61
Egypt	110 990 103	343 198	204 179	59.5	3 092	1 840
Ghana	33 475 870	3 914	1 081	27.6	117	32
Malawi	18 867 337	2 829	1 256	44.4	150	67
Mali	21 904 983	2 009	776	38.6	92	35
Mauritius	1 262 523	3 008	1 578	52.5	2 383	1 250
Namibia	2 567 012	3 439	2 502	72.8	1 340	975
Nigeria	203 304 492	41 431	20 881	50.4	204	103
Rwanda	14 094 683	7 411	3 805	51.3	526	270
RSA	59 893 885	85 601	63 122	73.7	1 429	1 054
Senegal	17 316 449	26 930	24 950	92.6	1 555	1 441
Zambia	20 017 675	3 429	2 531	73.8	171	126

5.5.3 Participation of Women in R&D

Female scientists add value in research by bringing in more creativity arising from their experience and inclusive approaches to work which expands general knowledge in the field of science and technology. It is therefore important to encourage women to venture around science and technology to optimally utilise their skills and knowledge at the same time make use the opportunity to participate in decision making for future development.

Table 5.14 Participation of women in R&D activities, HC

Country	Female R&D personnel	Female researchers	Female share of total R&D personnel (%)	Female share of total researchers (%)
Benin	293	177	21.7	21.9
Egypt	129 564	84 915	37.8	41.6
Ghana	1 181	344	30.2	31.8
Malawi	862	393	30.5	31.3
Mali	394	92	19.6	11.9
Mauritius	1 456	771	48.4	48.9
Namibia	1 784	1 238	51.9	49.5
Nigeria	13 002	6 393	31.4	30.6
Rwanda	2 364	996	31.9	26
RSA	41 880	29 658	48.9	47.0
Senegal	9 513	8 996	35.3	36.1
Zambia	991	671	28.9	26.5

Details of the participation of women in R&D activities are presented in **Table 5.14**. In all the ten countries, the share of both female R&D personnel and female researchers is below 50%. Republic of South Africa and Mauritius are almost catching up where the share of female R&D personnel is at 48,9% and 48.4% respectively. Looking at the rest of the countries, the shares of female R&D personnel and female researchers are less than 40%. As for female researchers, only three countries (Mauritius, Republic of South Africa and Egypt) recorded 48.9%, 47.0% and 41.6% respectively as a share of total researchers. The rest of the countries performed dismally where the share of female researchers was below 35%.

Table 5.15: Female R&D personnel by sector, HC

Area Surveyed	Country	Total female R&D personnel	Business	Government	Higher Education	Private Non-Profit
All (BUS GOV HE PNP)	Egypt	129 564	11.91	12.18	75.53	0.37
	Mauritius	1 456	3.78	33.52	60.92	1.79
	Malawi	862	1.39	34.45	56.38	7.77
	Mali	394	0.51	70.81	18.02	10.66
	Namibia	1 784	2.24	21.30	73.93	2.52
	Rwanda	2 364	16.58	24.96	33.16	25.30
	RSA	41 880	17.02	8.61	71.32	3.05
GOV/HE	Benin	293	-	29.01	70.99	-
	Nigeria	13 002	-	44.25	55.75	-
	Zambia	991	-	26.74	73.26	-
BUS/GOV	Ghana	1 181	61.47	38.53	-	-
HE	Senegal	9 513			100.00	

Distribution of female R&D personnel by sector is presented in **Table 5.15**. Egypt recorded the highest number of female R&D personnel at 129 564 followed by the Republic of South Africa and Nigeria at 41 880 and 13 002 respectively. Looking at the three sectors namely Business, Government and Higher Education, Egypt recorded the highest number of female

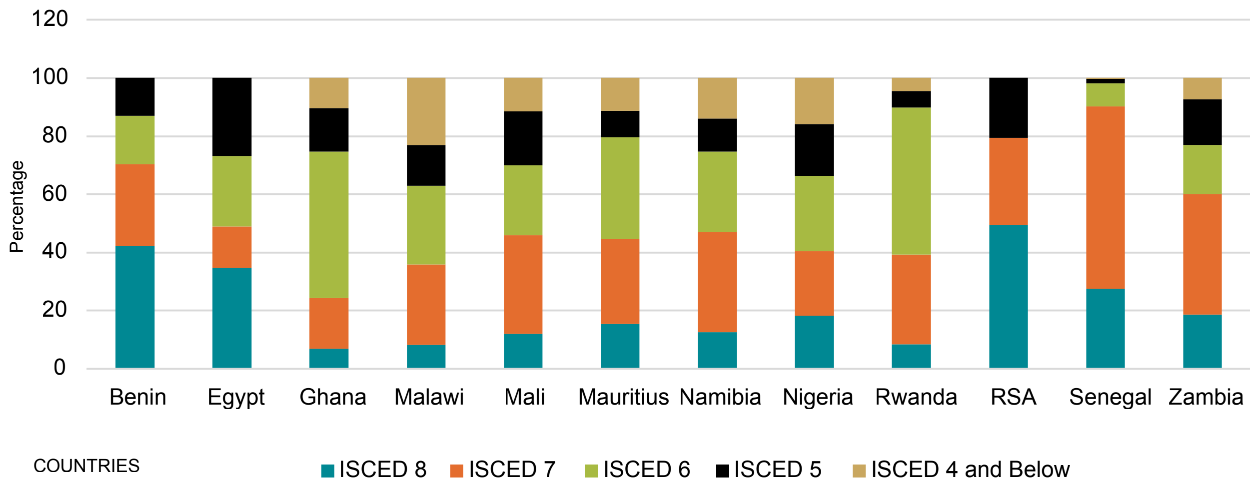
R&D personnel at 15 434, 15 782 and 97 865 respectively, where higher education accounted for 75.5% of the country's total female R&D personnel. Republic of South Africa followed with 7 128, 3 607 and 29 867 respectively and higher education accounted for 71.3% of the total female R&D personnel. Although Nigeria did not have data for business sector, the country ranked third in Government and Higher Education sectors with higher education accounting for 55.8% of total female R&D personnel. Mali was the only country with fewer female R&D personnel in the Higher Education sector when compared to Government sector.

Table 5.16 Female R&D personnel by qualification, HC

Coverage	Country	Female R&D personnel	ISCED 8	ISCED 7	ISCED 6	ISCED 5	ISCED 4 and below
BUS/GOV/ HE/PNP	Egypt	129 564	34.72	14.23	24.19	26.85	-
	Mali	394	11.93	34.01	24.11	18.53	11.42
	Malawi	862	8.24	27.61	27.03	14.04	23.09
	Mauritius	1 456	15.38	29.12	35.03	9.27	11.20
	Namibia	1 784	12.56	34.53	27.63	11.38	13.90
	Rwanda	2 364	8.42	30.84	50.51	5.84	4.40
	RSA	41 880	49.58	29.79	-	20.63	-
GOV/HE	Benin	293	42.32	27.99	16.72	12.97	-
	Nigeria	13 002	18.26	22.06	25.96	17.93	15.80
	Zambia	1 717	20.91	45.54	15.43	12.46	5.65
BUS/GOV	Ghana	1 181	6.86	17.53	50.30	15.07	10.25
HE	Senegal	9,513	27.58	62.71	7.97	1.40	0.34

Table 5.16 and **Figure 5.5** show the headcount and the percentage share of female R&D personnel by qualification. Benin had the highest share of female R&D personnel with a PhD degree. Put differently, of the 293 women R&D personnel reported by Benin, 42.3% have PhD degrees, followed by Egypt at 34.7%.

Figure 5.5 Percentage distribution of female personnel by qualification



Both countries had no female R&D personnel with ISCED 4 and below qualifications. Ghana, at 50.3%, had the largest cohort of R&D female personnel with a Bachelor's degree. Ghana and Zambia had the least number of female R&D personnel with ISCED 4 level or below qualifications at 10.2% and 7.4% respectively.

Table 5.17 Female R&D personnel by field of R&D, HC

Coverage	Country	Total	Natural sciences	Engineering & technology	Medical sciences	Agricultural sciences	Social Sciences	Humanities	Not classified
All (BUS,GOV ,HE,PNP)	Egypt	129 564	12.99	10.72	34.98	9.64	20.25	11.41	-
	Malawi	862	6.15	5.10	26.22	18.68	16.36	4.06	23.43
	Mali	394	8.88	4.31	5.08	52.54	12.18	7.11	9.90
	Mauritius	1 456	16.96	11.20	8.52	11.54	18.89	16.07	16.83
	Namibia	1 784	14.01	4.54	12.72	5.55	23.54	1.91	37.72
	Rwanda	2 364	13.49	17.17	24.66	10.28	23.39	6.81	4.19
	RSA	41 880	25.75	6.32	28.32	5.90	28.42	5.29	-
GOV HE	Benin	293	10.92	5.12	6.14	41.98	3.41	3.41	29.01
	Nigeria	13 002	14.48	6.28	12.64	15.05	14.15	7.95	29.43
	Zambia	991	12.51	3.73	31.58	23.31	21.80	6.96	0.10
BUS GOV	Ghana	1 181	9.82	17.70	21.59	14.14	12.02	13.04	11.69
HE	Senegal	9 513	22.12	3.20	13.83	2.92	34.35	22.68	0.89

Details of female R&D personnel by field of R&D are presented in **Table 5.17**. Egypt has the highest number of female R&D personnel in all fields of R&D followed by the Republic of South Africa and Nigeria. 35% of female R&D personnel in Egypt are in medical sciences, the Republic of South Africa has 28% and Nigeria 15% of the female R&D personnel in the same field of R&D. Nigeria reported the highest number of female R&D personnel at 1,952 or 73% of the total of those not classified. All the countries display varied numbers of female R&D personnel in different fields of R&D. This is a major challenge as there is no comparability among the countries due to their diverse institutional framework.

Table 5.18 Female R&D personnel by Age (HC)

Coverage	Country	Tot. female R&D personnel	Under 25	25-34	35-44	45-54	55-64	65+	Not classified
All (BUS/ GOV/HE/ PNP)	Mali	394	0.25	19.54	46.95	27.16	5.58	0.51	-
	Rwanda	2 364	8.29	45.43	31.98	10.62	3.55	0.13	-
	Namibia	1 784	2.19	22.65	30.49	18.05	9.02	17.60	-
GOV/HE	Benin	293	5.80	33.11	38.91	14.68	7.51	-	-
	Nigeria	13 002	8.69	16.32	32.14	25.63	9.06	8.16	-
	Zambia	991	0.30	18.87	37.54	26.84	14.03	2.42	-
BUS/GOV	Ghana	1 181	2.37	36.16	42.42	15.07	3.73	0.25	-
HE	Senegal	9 513	1.56	33.52	24.90	24.65	11.34	0.89	3.13

Table 5.18 depicts the female R&D personnel by sector and age. The number of female R&D personnel were low when compared with their male counterparts in the same age groups across all countries. The table shows all countries had the highest number of female R&D personnel in the age group 35-44 years. Of interest is the number of female R&D personnel above the age of 65 in Nigeria, which made up 7.3% of total female R&D personnel while those younger than 25 were only 2.3% of the female R&D personnel.

Table 5.19 FTE for female R&D personnel

Area Surveyed	Country	Total FTE	Business	Government	Higher Education	Private Non-Profit
All *BUS/ GOV/ HE/PNP	Egypt	122 422.3	59 744.3	15 386.2	46 857.1	434.7
	Malawi	468.1	5.0	275.8	165.1	22.2
	Mali	322.6	-	228.0	58.6	36.0
	Mauritius	764.5	22.1	313.2	406.7	22.5
	Namibia	446.6	29.4	48.1	335.5	33.6
	Rwanda	1 151.0	197.0	290.7	364.3	299.0
	RSA	22 266.2	6 300.1	2 774.9	12 086.3	1 104.9
GOV/HE	Benin	186.0	-	78.0	108.0	-
	Nigeria	2 050.0	-	1 323.2	726.8	-
	Zambia	460.6	-	243.8	216.8	-
BUS/GOV	Ghana	930.2	566.4	363.8	-	-
HE	Senegal	-	-	-	2 011.02	-

Details of FTE for female R&D personnel are presented in **Table 5.19**. Egypt recorded the highest FTE for female R&D personnel at 122 422.3, followed by Republic of South Africa at 22 266.2 and Nigeria at 13 002.0. The rest of the countries recorded less than 1 000 total FTE for female R&D personnel. Egypt still recorded high total FTE for female R&D personnel at 49% in business sector 12% in government, 38% in higher education and 0.4% in PNP. Republic of South Africa reported high total FTE for female R&D personnel in higher education at 54% followed by business sector at 28%, government sector at 13% and Private Non-Profit at 5%. The rest of the countries reported less than 500 total FTE for female R&D personnel in both government and higher education sectors although Ghana did not have data for Higher Education sector.

Table 5.20 Female researchers by sector (HC)

Area Surveyed	Country	Total female researchers	Business	Government	Higher Education	Private Non-Profit
BUS/GOV/HE/ PNP	Egypt	84 915	9.39	12.36	78.01	0.24
	Malawi	393	1.53	11.45	84.99	2.04
	Mauritius	771	1.56	32.81	64.59	1.04
	Namibia	1 238	2.18	27.46	68.34	2.02
	Rwanda	996	10.64	16.97	50.40	21.99
	RSA	29 658	5.09	6.19	87.79	0.92
GOV/HE/PNP	Mali	92	-	58.70	36.96	4.35
GOV/HE	Benin	177	-	14.12	85.88	-
	Nigeria	6 393	-	33.63	66.37	-
	Ghana	344	51.45	48.55	-	-
BUS/GOV	Zambia	671	-	15.80	84.20	-
HE	Senegal				100.00	

Table 5.20 presents details of female researchers by sector. Egypt, Republic of South Africa and Nigeria reported high numbers of female researchers in that order. All countries except Ghana submitted data in government and higher education. In Egypt, female researchers in Higher Education sector accounted for 78%, the Republic of South Africa 88% and Nigeria 66%. As for government sector, Egypt recorded 12%, the Republic of South Africa 6.2% and Nigeria 34%. It is to be noted that, the high concentration of female researchers in both government and higher education is also reflected in the rest of the countries except Ghana which did not collect data in Higher Education sector. Mali is the only country that reported fewer female researchers in Higher Education sector compared to government sector. Although four countries namely Mali, Benin, Nigeria and Zambia did not collect data in the business sector, those that submitted reported fewer female researchers in business sector compared to government and Higher Education sectors save for Ghana which did not have data for the later sector.

Table 5.21 Female researchers by qualification (HC)

Coverage	Country	Total female researchers	ISCED 8	ISCED 7	ISCED 6	ISCED 5	ISCED 4 and below
BUS/GOV/HE/PNP	RSA	29 658	68.42	27.58	-	3.99	-
	Namibia	1 238	17.45	42.73	20.11	8.32	11.39
	Rwanda	996	19.18	50.20	28.31	1.41	0.90
GOV/HE	Benin	177	67.80	27.12	5.08	-	-
	Nigeria	6 393	35.95	32.79	16.89	4.69	9.68
	Zambia	671	26.23	57.53	15.35	0.89	-
BUS/GOV	Ghana	344	21.80	40.41	27.62	9.88	0.29
HE	Senegal	8 996	27.65	64.27	8.08	-	-

Except for South Africa and Benin with the highest concentration of PhD degree holders or equivalent (ISCED 8), the remaining countries have more master’s degrees or equivalent (ISCED 7) in Table 5.21 when it comes to female researchers by qualification.

Table 5.22 Female researchers by field of R&D

Coverage	Country	Total	Natural sciences	Engineering & technology	Medical sciences	Agricultural sciences	Social sciences	Humanities	Classified elsewhere	Not classified
All	Egypt	84,915	12.28	8.40	36.45	9.35	21.46	12.06		-
	Malawi	393	7.89	6.87	34.10	10.18	23.16	4.58		13.23
	Mali	92	15.22	11.96	7.61	25.00	16.30	19.57		4.35
	Mauritius	771	15.56	13.88	4.93	10.25	28.53	23.48		3.37
	Namibia	1 238	13.81	4.52	14.54	5.82	26.58	2.42	5.33	26.98
	Rwanda	996	14.26	19.98	24.30	9.44	22.79	7.93		1.31
	RSA	29 658	27.46	6.59	19.68	5.31	34.46	6.51		-
GOV/HE	Benin	177	14.12	8.47	9.60	30.51	5.65	5.65		25.99
	Nigeria	6 393	17.80	7.84	15.24	11.11	13.78	7.04		27.20
	Zambia	671	14.31	3.13	34.13	16.99	21.91	9.54		-
BUS/GOV	Ghana	344	15.41	15.99	9.01	23.55	14.53	12.79		8.72
HE	Senegal	8 996	22.49	2.58	13.76	2.27	34.70	23.25	0.94	-

Details of the share of female researchers in the field of R&D are presented in Table 5.22. Egypt reported the highest number of female researchers in all sectors followed by Republic of South Africa and Nigeria. Benin and Ghana are the only two countries that reported a higher number of female researchers in the Engineering and Technology fields than in the Social Sciences and Humanities. All countries, except Mauritius and Republic of South Africa, reported a higher number of female researchers in the Agricultural field of R&D than in the Engineering and Technology fields. 72% of the total number of female researchers not classified were from Nigeria. Furthermore, the number of researchers that are not classified pause a challenge to countries necessitating serious intervention.

Table 5.23 Female researchers by age, HC

Coverage	Country	Total female researchers	Under 25	25-34	35-44	45-54	55-64	≥65	Not classified
BUS/GOV/ HE/PNP	Rwanda	996	5.82	30.42	38.35	18.67	6.53	0.20	
	Namibia	1 238	1.94	18.90	27.46	16.48	10.18	1.70	23.34
GOV/HE	Benin	177	1.13	35.03	39.55	15.25	9.04	-	
	Zambia	671	0.30	15.35	38.75	28.91	13.71	2.98	
BUS/GOV	Ghana	344	3.78	23.84	53.20	14.24	4.07	0.87	

Details of FTE for female researchers by sector are presented in Table 5.24. The two sectors, Government and hhigher Education, recorded a high concentration of FTE for female researchers. Egypt registered the highest FTE for female researchers in all the sectors except Private Non-Profit sector which ranked second after the Republic of South Africa, which was second in business (1 131.8) and higher education (10 293.6).

Table 5.24 FTE for female researchers by sector

Area surveyed	Country	Total FTE	Business	Government	Higher education	Private Non-Profit
BUS/GOV/HE/ PNP	Egypt	38 670.8	3 667.9	10 096.2	24 723.1	183.6
	Malawi	145.7	2.7	43.4	94.5	5.1
	Mauritius	354.8	9.0	125.3	214.5	6.0
	Namibia	304.5	22.7	28.9	231.5	21.4
	Rwanda	471.3	56.3	94.7	210.6	109.7
	RSA	12 963.7	1 131.8	1 324.6	10 293.6	213.7
GOV/HE	Benin	102.4	-	20.8	81.6	-
	Nigeria	1 452.9	-	774.0	678.9	-
	Zambia	274.1	-	105.8	168.3	-
GOV/HE/PNP	Mali	79.3	-	47.0	28.3	4.0
BUS/GOV	Ghana	239.8	116.2	123.6	-	-
HE	Senegal	1 779.9	-	-	1 779.9	-

Although Nigeria covered only two sectors, Government and Higher Education, the country still recorded significantly high FTE for female researchers in the two sectors, 2 150.0 and 4 243.0 respectively. Mauritius registered (125.3, 214.5), Zambia (105.8, 216.8) and Rwanda registered 99.0 and 149.0 in government and higher education sectors respectively. While Egypt registered the highest FTE for female researchers in the Business sector (3,667.9), Ghana and Malawi reported 116.2 and 2.7 respectively in the same sector. Mali reported the least FTE for female researchers in the Higher Education (28.3) and Private Non-Profit (4.0) sectors.

5.6 R&D EXPENDITURE

5.6.1 Gross Domestic Expenditure on R&D (Countries with Comprehensive Data)

5.6.1.1 GERD and R&D Intensity

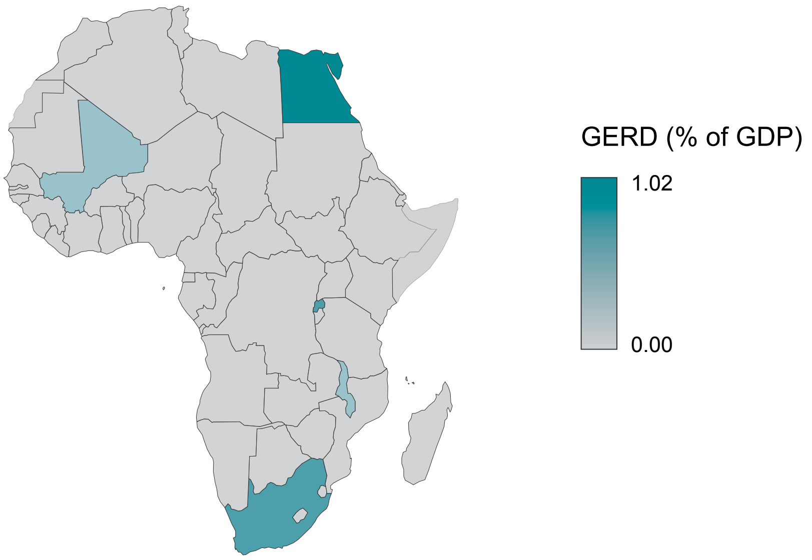
Of the ten countries that submitted data on R&D expenditure towards this version of the AIO, six provided data for all sectors as per the expectation. However, it is important that where samples have been surveyed the process goes up to the extrapolation to reflect the target population of the sector before adding up to the well-known sectors of R&D performance to compute GERD. Hence, GERD as a percentage of GDP may be calculated. Table 5.2 displays the R&D intensity, GERD (in PPP$ M) and GERD per capita (in PPP$) for these six countries.

Table 5.25 GERD indicators for AU Member States with all four sectors of R&D performance

Countries	GERD (PPP$ M)	GERD (% of GDP)	GERD per capita (PPP$)
Egypt	17 084.73	1.02	153.93
Malawi	53.12	0.00	2.82
Mali	0.09	0.00	0.00
Mauritius	104.95	0.31	83.13
Rwanda	222.38	0.76	17.33
South Africa	5 376.04	0.62	90.52

Key observations: Egypt spends the most with about $17.1-billion followed by South Africa with $5.4-billion. There's a huge gap between these two and the rest. Mali has negligible R&D spending at just $0.09-million. Beyond Egypt, only South Africa and Rwanda reported R&D intensity levels exceeding 0.5%. In contrast, Malawi, Mali and Mauritius recorded R&D intensities below 0.5%.

Figure 5.6 R&D intensities for Egypt, Malawi, Mali, Mauritius, Rwanda and South Africa



Egypt is the only African Union (AU) Member State that has achieved the minimum target of 1% of GDP investment in Research and Development (R&D).

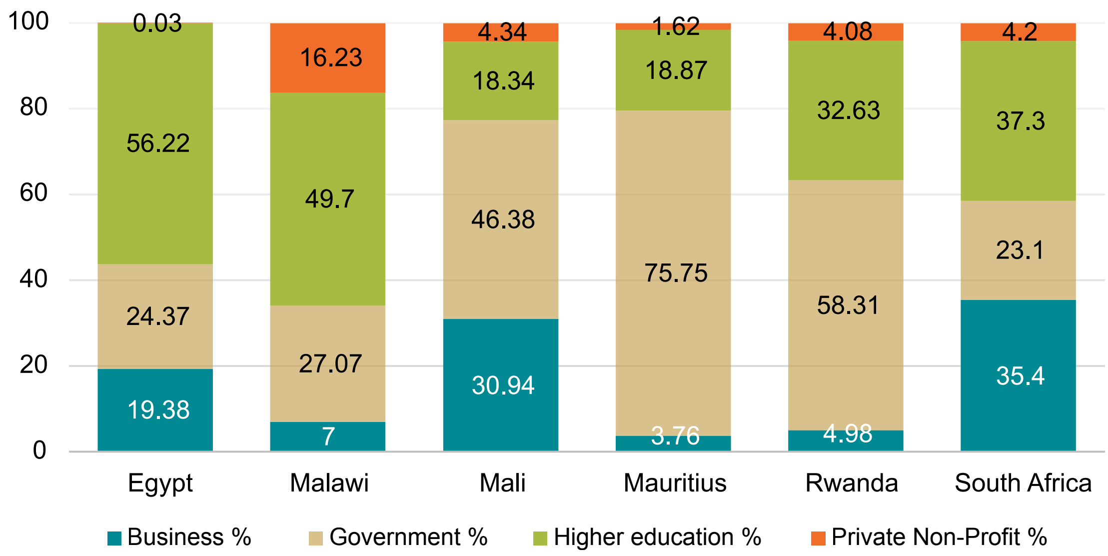
Main inferences: GERD per capita, which represents the amount of R&D activity normalised to the population size, varies significantly among these countries. This variation, ranging from 2.82 to 153.93 PPP$, highlights the differing priorities and resources allocated to R&D across the region.

- There's a significant north-south divide in R&D activity, with Egypt leading substantially in all metrics
- The data suggests a correlation between economic development and R&D investment, as relatively more developed economies (Egypt, South Africa, Mauritius) show higher R&D spending
- Rwanda stands out for having a relatively high R&D intensity (0.76% of GDP) despite lower absolute numbers, suggesting a strategic priority on research and development
- Countries like Mali and Malawi show extremely low R&D investment, indicating significant challenges in prioritising research and development, likely due to other pressing developmental needs

5.6.1.2 R&D Activity in Institutional Sectors

The evidence presented in Figure 5.7 provides the share of GERD by each sector of performance in percentages for the six countries that reported data on all sectors.

Figure 5.7 GERD by sector of performance in Egypt, Malawi, Mali, Mauritius, Rwanda and South Africa



Key observations: the data suggests an inverse correlation in government sector activity and business participation. Countries with high government R&D (Mauritius: 75.75%, Rwanda: 58.31%) show very low business participation (3.76% and 4.98% respectively). Countries with lower government activity (South Africa: 23.1%, Egypt: 24.37%) demonstrate higher business participation (35.4% and 19.38% respectively).

- **Business sector:** South Africa leads in business sector contribution to R&D with 35.4%, followed by Mali with significant involvement at 30.94%. Egypt has moderate business participation, contributing 19.38%. In contrast, business participation is very low in Mauritius (3.76%) and Rwanda (4.98%)
- **Government role:** Mauritius has the highest government contribution to R&D, accounting for 75.75%, followed by Rwanda at 58.31% and Mali at 46.38%. In contrast, other countries show lower levels of government participation, ranging between 23% and 27%
- **Higher Education sector:** the Higher Education sector dominates R&D activity in Egypt, accounting for 56.22% and in Malawi, with 49.70%. It also has a strong presence in South Africa, contributing 37.3%. However, in countries like Mali and Mauritius, the share of higher education in R&D is relatively lower, at around 18%

- **Private Non-Profit sector:** Malawi has the highest private non-profit contribution to R&D at 16.23%. Most other countries show minimal private non-profit involvement, typically ranging between 1% and 4%. In Egypt, private non-profit participation in R&D is nearly negligible, at just 0.03%

Key insights

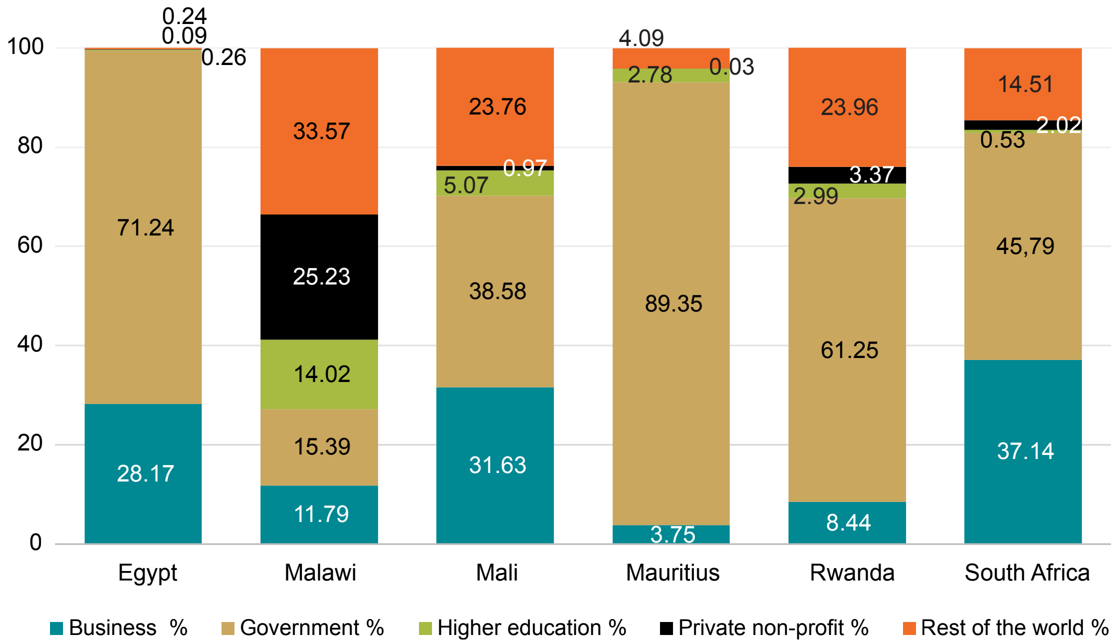
- **Private sector engagement:** national R&D profiles vary significantly across sectors, with some countries relying heavily on government-driven R&D efforts, such as Mauritius and Rwanda, while others, like South Africa, exhibit a more balanced distribution across sectors. Higher education plays a pivotal role in R&D in many nations, particularly in Egypt and Malawi. In contrast, the business sector's involvement is stronger in South Africa and Mali, though most countries still struggle to attract substantial private sector R&D investment,

  Low business participation in R&D may signal challenges in fostering industry-academia collaboration, limited technological capabilities in local industries, insufficient resources for R&D investment or a focus on technology adoption over innovation. Additional barriers might include a misalignment between research priorities and market needs or a risk-averse business environment. From a policymaker's perspective, high government involvement in R&D might indicate underdeveloped private sector research infrastructure, a lack of incentives for private investment in R&D or underdeveloped pathways for research commercialisation

- **Structural implications:** The R&D activity distribution suggests different R&D priorities and capabilities. Countries with higher business sector involvement might have better research commercialisation, as most experimental development typically takes place here

5.6.1.3 Sources of Funding for R&D

Figure 5.8 R&D expenditure in Egypt, Malawi, Mali, Mauritius, Rwanda and South Africa by sources of funding



Key observations: The data reveals striking variations in R&D funding patterns across African countries. Government funding dominates the research landscape in several nations, with Mauritius showing an extraordinary 89.35% dependence on government sources, followed by Egypt at 71.24% and Rwanda at 61.25%. In contrast, South Africa and Mali demonstrate more balanced funding profiles, with government contributions at 45.79% and 38.58% respectively. The business sector's contribution varies significantly, with South Africa leading at 37.14%, followed closely by Mali at 31.63% and Egypt at 28.17%. However, business participation remains notably low in Mauritius at just 3.75%.

International funding plays a crucial role in certain countries, particularly Malawi, where it accounts for 33.57% of total R&D funding. Rwanda and Mali also show substantial reliance on international sources at approximately 24% each, while Egypt and Mauritius demonstrate minimal international funding dependency. Higher education funding remains generally low across all countries, with Malawi being the exception at 14.02%. Similarly, private non-profit funding is minimal in most countries, though Malawi again stands out with 25.23% contribution from this sector.

Main insights: the funding patterns reveal distinct research ecosystem archetypes across African nations. Countries with stronger economies, notably South Africa and Egypt, demonstrate more robust business sector participation in R&D funding, suggesting better integration between industry and research. This contrasts sharply with the government-centric models seen in Mauritius and Egypt, where high government funding percentages might indicate either strong state commitment to research or, more concerning, underdeveloped private research capacity. The nearly 90% government funding in Mauritius, coupled with low R&D intensity (as shown in Figure 5.8), suggests an underdeveloped research infrastructure. In contrast, Egypt's substantial government support for R&D, along with its relatively high R&D intensity, points to the potential for imminent rapid growth in private sector R&D participation. This latter inference arises from historical observations of the trajectory of other countries where private sector funding has progressively increased and now leads R&D investment.

The significant variation in international funding[20] dependency offers insights into research sustainability and autonomy. Malawi's high reliance on both international and private non-profit funding suggests potential vulnerability in its research ecosystem, while also indicating strong international research partnerships. The minimal higher education funding across most countries raises concerns about long-term research capacity building and the development of domestic research capabilities.

Funding models:

- Government-centric: Mauritius, Egypt, Rwanda
- Diversified: Mali, South Africa
- Aid-dependent: Malawi

These patterns have profound implications for research sustainability and innovation potential. Countries showing more balanced funding distributions, like South Africa, likely possess more resilient research ecosystems better equipped to maintain consistent research output and innovation. Conversely, nations heavily dependent on single funding sources may face challenges in maintaining research continuity and adapting to changing circumstances. The low business sector participation in several countries – perhaps all – suggests a critical need for stronger industry-academia linkages and more effective research commercialisation pathways, which are essential for transforming research into economic value.

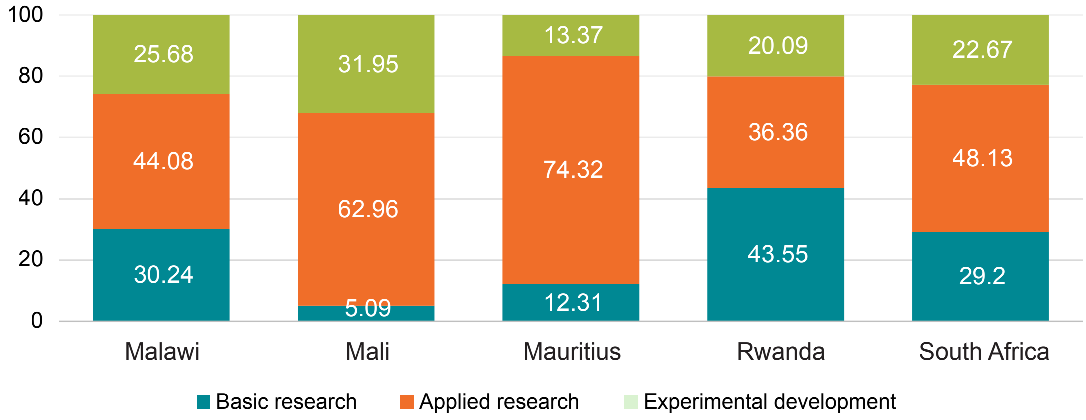
The high extent of external sources of funding for R&D may indicate knowledge links, collaborations and interactions with the international research community but there is need to increase domestic investment in R&D in Africa, especially in those countries where the funds come in the form of development aid.

5.6.1.4 R&D by Types of Research Conducted

R&D expenditure by type of research for the six countries which covered all four institutional sectors is presented in Figure 5.9.

20 Private non-profits typically act as conduits for overseas donor funding.

Figure 5.9 GERD by type of R&D for Malawi, Mali, Mauritius, Rwanda and South Africa (no data available for Egypt)



Key observations:

- **Distribution patterns:** not surprisingly, applied research dominates in most countries (36-74%). Basic research shows the widest variation (5-44%) among the five countries surveyed. Experimental development is consistently the lowest (13-32%)
- **Country-specific patterns:** Tthe distribution of R&D types reveals distinct research priorities across African nations. Rwanda stands out with the highest proportion of basic research at 43.55%, significantly above other countries in the sample. Mauritius shows a strong focus on applied research, dedicating 74.32% of its R&D efforts to this category, while maintaining relatively lower percentages in basic research (12.31%) and experimental development (13.37%). Mali demonstrates a similar emphasis on applied research at 62.96%, but with a notably low basic research component of just 5.09%. South Africa and Malawi show more balanced distributions, with South Africa allocating 48.13% to applied research, 29.20% to basic research and 22.67% to experimental development, while Malawi's distribution follows a similar pattern with 44.08%, 30.24% and 25.68% respectively. Egypt had no data on research types

Main insights: high levels of applied research typically indicate a strong focus on practical problem-solving. When this is accompanied by low levels of experimental development, it may suggest either a limited capacity for industrial R&D or difficulties in translating research into commercialised products and services in these five African countries. In examining specific countries, distinct strategic modes of research and development appear to emerge:

- **Knowledge generation model (**Rwanda**):** prioritises basic research
- **Problem-solving Mmodel (**Mauritius**):** emphasises applied research
- **Balanced approach (**South Africa, Malawi**):** demonstrates a more even distribution between basic and applied research, along with experimental development

These different modes reflect the varying priorities and capabilities in national R&D strategies across an admittedly small sample of African countries.

5.6.2 R&D Expenditure by Sector of Performance

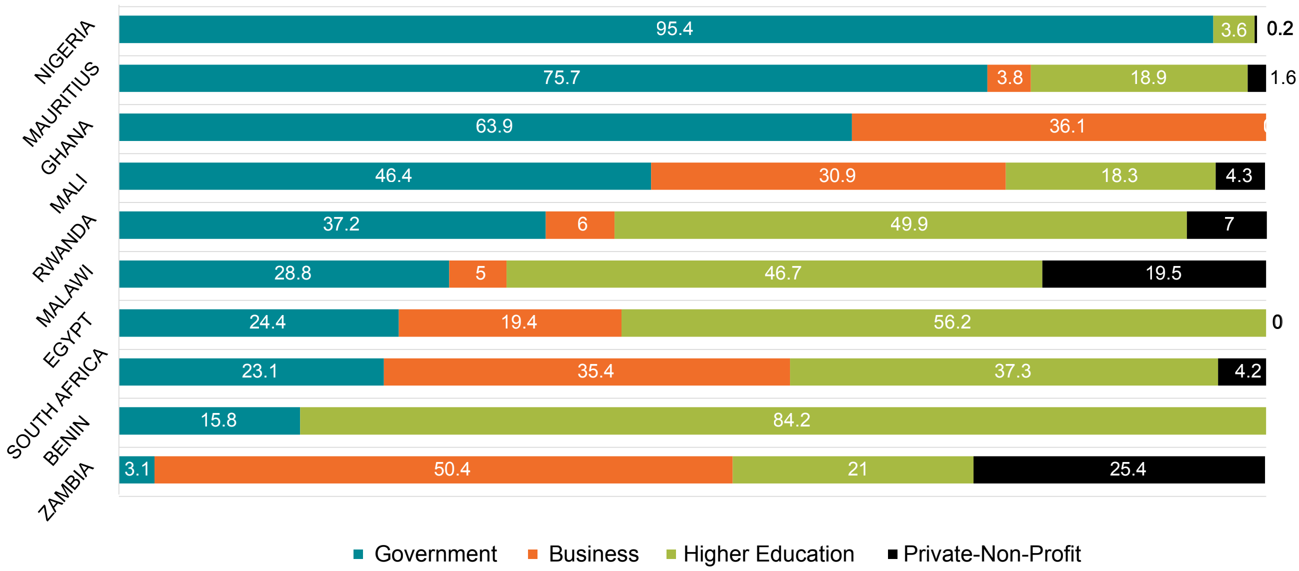
Figure 5.7 illustrates GERD by sector of performance (institutional sectors) and country. The share of GERD among the four sectors was skewed towards certain sectors across all countries. The bulk of the R&D performance in the countries shown was performed by the Government sector, which in this report was covered by all countries but at different levels. Ghana, Mauritius and Nigeria had GOVERD of more than 60.0% at 63.9, 75.7% and 95.4%, respectively. Zambia, Benin, South Africa and Egypt had less than a quarter of their GERD in GOVERD at 3.1%, 15.8%, 23.1% and 24.4%, respectively. Within the African Union (AU), the business sector's contribution to research and development (R&D) remained weak. Notably, Zambia stood alone among AU Member States: it was the only one where business enterprise R&D expenditure

(BERD) exceeded 50% of its gross domestic expenditure on R&D (GERD) – and even then, only marginally. HERD was reported in all countries but Ghana. Egypt and Rwanda, with Benin performing almost all its R&D in the Higher Education sector, at just over 84%. BERD and PNPERD were low across most countries.

5.6.2.1 Business Expenditure on R&D (BERD)

The Business sector R&D was reported by seven out of twelve countries, with Egypt and South Africa leading at 3 311.7-million PPP$ and 1 904.5-million PPP$. Notwithstanding the little or no contribution to BERD from other African countries, Egypt and South Africa contributed 99.0% (5 216.2-million PPP$) of the AU's BERD. The Business sector in Egypt spent more on R&D but had a relatively lower BERD per capita when compared to South Africa, which spent just over half of Egypt's BERD.

Figure 5.10 GERD by sector of R&D performance



Source: ASTI IV R&D surveys | No Expenditure data for Namibia and Senegal | Incomplete GERD: Benin, Ghana, Nigeria,

Table 5.26 Business expenditure on R&D (BERD)

Countries	BERD	BERD	BERD per capita
	(PPP$ M)	(% of GDP)	(PPP$)
Egypt	3 311.73	0.2	29.84
Ghana	32.03	0.02	1.05
Malawi	3.72	0	0.2
Mali	0.03	0	0
Mauritius	3.95	0.01	3.13
Rwanda	11.08	0.04	0.01
South Africa	1 904.45	0.22	32.07

Source: ASTI IV R&D surveys
No Expenditure data for Namibia and Senegal

Business sector data plays a crucial role in shaping industrialisation strategies across the continent. Although a comprehensive mapping of all major sectors within a country's National System of Innovation (NSI) is ideal, concentrating on the business sector alone can provide significant insights. This focus is particularly relevant due to the typically higher prevalence of experimental development in the business sector compared to others. As a result, analysing data from the business sector enables informed inferences regarding the propensity for innovation driven by R&D activities within that sector. This approach not only highlights the importance of the business sector in fostering innovation but also underscores its pivotal role in advancing overall economic development.

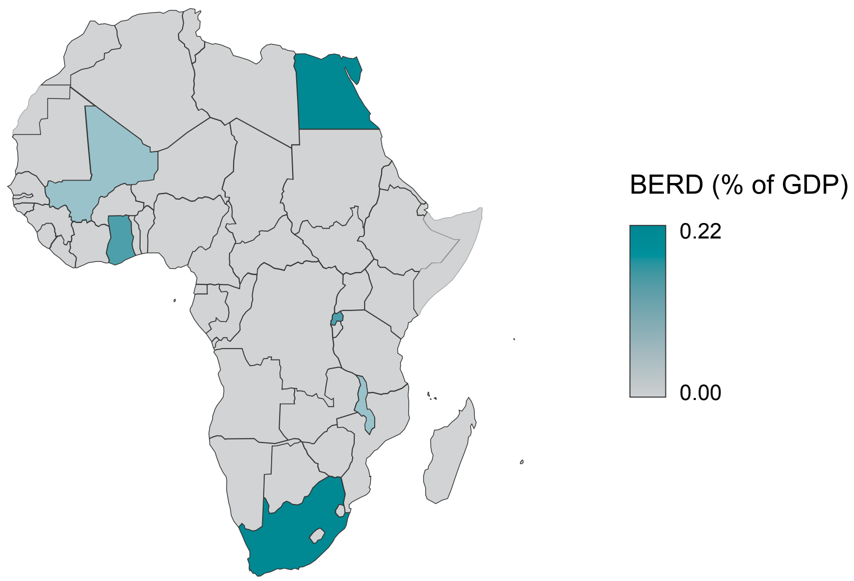
Moreover, it is reasonable to assume that funding patterns in the business sector align with its R&D activity patterns. Firms typically finance their own R&D efforts to generate new knowledge, processes and technologies, which are crucial for driving product innovations, such as new goods and services. In most cases, apart from South Africa and Mauritius – where the business sector also received significant funding from other sectors – no notable external funding was recorded in the other five countries. This suggests a strong reliance on internal resources for business-sector innovation in those contexts.

Only seven countries have provided data on business expenditure on R&D (BERD). BERD and associated variables are provided in Table 5.26.

Key observations: the range of values spans from 0.03 million PPP$ in Mali to 3 311.73-million PPP$ in Egypt, illustrating three distinct tiers of economic performance. The high tier is led by Egypt, with 3 311.73-million PPP$, followed by South Africa at 19 04.45-million PPP$. The medium tier includes Ghana at 32.03-million PPP$ and Rwanda at 11.08-million PPP$. In contrast, the low tier consists of Mauritius at 3.95-million PPP$, Malawi at 3.72-million PPP$ and Mali at a minimal 0.03-million PPP$ (Table 5.26).

Business Expenditure on Research and Development (BERD) per capita shows significant disparities across countries. South Africa leads with 32.07-PPP$, followed closely by Egypt at 29.84-PPP$. There is a notable gap to the next tier, with Mauritius at 3.13 PPP$. Most other countries report BERD figures below 3 PPP$ per capita. The disparities are stark, with the ratio of the highest to the lowest exceeding 32 000:1, highlighting substantial differences in R&D investment per individual across nations.

Figure 5.11 BERD as a percentage of GDP for Egypt, Malawi, Mali, Mauritius, Rwanda, South Africa and Ghana



Business Expenditure on Research and Development (BERD) as a percentage of GDP is generally low across all countries, with most falling below 0.25%. The highest figures are recorded in South Africa at 0.22% and Egypt at 0.20%. In contrast, many countries register BERD percentages below 0.05%, indicating minimal investment in research and development relative to their GDP. Specifically, Mali and Malawi exhibit negligible percentages, reflecting significant challenges in their R&D funding and innovation capacities (Figure 5.11).

Main Insights

Structural patterns. There is a strong correlation between the size of a country's GDP and its Business Expenditure on Research and Development (BERD). Business R&D activities are predominantly concentrated in more industrialised economies, such as Egypt and South Africa, where the private sector plays a significant role in driving innovation. In contrast, smaller economies show limited private sector engagement in R&D, reflecting their lower capacity for industrialisation and innovation. This pattern underscores the critical relationship between economic scale and the ability to invest in research and development within the business sector.

Country-specific analyses. Low levels of BERD in all countries indicate several structural challenges. First, they suggest limited private sector innovation capacity, with businesses investing minimally in R&D activities. Second, these low levels point to a heavy reliance on public sector R&D to drive research and development efforts. Third, they may highlight difficulties in commercialising research outputs, potentially due to gaps in infrastructure, funding or market readiness. Lastly, the situation underscores the need for stronger linkages between industry and research institutions to enhance collaboration and foster greater private sector engagement in innovation.

In Mauritius, despite a strong focus on applied research of 74.32% (Figure 5.9), the country exhibits low Business Expenditure on Research and Development (Table 5.26). This suggests that applied research is primarily conducted within the public sector, indicating a potential disconnect between the research focus and business sector engagement in R&D activities.

In Rwanda, a high proportion of basic research of 43.55% (Figure 5.9) coupled with low BERD (Table 5.26) points to a research system that is predominantly led by government and academic institutions. This may reflect an early stage of private sector R&D development, with limited business involvement in driving innovation at this stage

5.6.2.2 Government R&D Expenditure Indicators

The results for government expenditure on R&D performed in 10 countries are shown in Table 5.27.

Egypt led in R&D performed in the government sector. At 48% of GOVERD captured for the countries shown, Egypt was first and followed by Nigeria, which spent 34%. South Africa was in third position and spent about 14% of AU's GOVERD (Table 5.27). These three countries spent about 97% of the total GOVERD. Zambia and Mali spent the least at 0.02-million PPP$ and 0.04-million PPP$, respectively. Rwanda had the highest GOVERD as a percentage of GDP (0.44%) and the GOVERD intensity of Malawi, Mali and Zambia was negligible. Mauritius had the GOVERD below of Rwanda, South Africa, Nigeria and Egypt, but its GOVERD per capita was the highest among all countries.

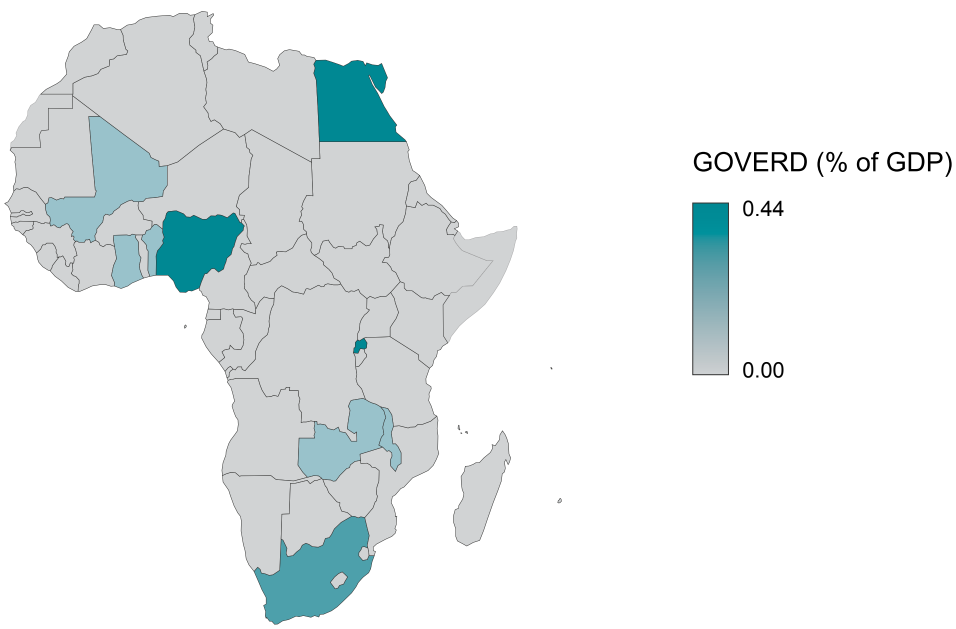
Table 5.27 Government expenditure on R&D, GOVERD

Countries	GOVERD (PPP$ M)	GOVERD (% of GDP)	GOVERD per capita (PPP$)
Benin	8.93	0.02	0.67
Egypt	4 164.36	0.25	37.52
Ghana	58.93	0.03	0.03
Malawi	14.38	0.00	0.76
Mali	0.04	0.00	0.00
Mauritius	79.50	0.23	62.97
Nigeria	2 922.61	0.27	14.38
Rwanda	129.66	0.295	0.06
South Africa	1 242.69	0.14	20.92
Zambia	0.02	0.00	0.00

Source: ASTI IV R&D surveys | No Expenditure data for Namibia and Senegal

Key observations: government expenditure on R&D shows remarkable variation across African countries, with absolute spending levels ranging from negligible amounts in Zambia and Mali to substantial investments in Egypt and Nigeria. GOVERD is relatively high in most African countries with Egypt, Nigeria and South Africa spending more than $1-billion on R&D performed by public institutions. Egypt leads in absolute terms with GOVERD of 4 164.36-million PPP$, followed by Nigeria at 2 922.61-million PPP$ and South Africa at 1 242.69-million PPP$. The per capita spending reveals yet another pattern, with Mauritius leading at 62.97 PPP$ per person, followed by Egypt at 37.52 PPP$ and South Africa at 20.92 PPP$. It is important to note that Mauritius had the highest GOVERD per capita in 2022 compared to Egypt which had the highest GOVERD spending on R&D in the same year due to differences in population size.

Figure 5.12 Government expenditure on R&D (GOVERD) as a percentage of GDP for Benin, Egypt, Ghana, Malawi, Mali, Mauritius, Nigeria, Rwanda, South Africa and Zambia



The proportion of GOVERD as a percentage of GDP for the 10 countries ranges from as low as 0.00% for Mali, Malawi and Zambia to a high of 0.44% for Rwanda (Figure 5.12). Large African economies such as Nigeria (0.27%), Egypt (0.25%) and South Africa (0.14%) are in the top five that spend a lot proportionally on R&D within their government sectors. Several countries, including Mali and Zambia, show minimal investment across all metrics.

Main Insights

The disparate patterns in government R&D expenditure reflect varying national priorities, economic capabilities and development strategies across Africa. The high absolute spending in Egypt and Nigeria demonstrates these larger economies' capacity to mobilise substantial resources for research, while Rwanda's leading position in GDP-relative spending suggests a strong policy commitment to R&D despite more limited resources. Mauritius's high per capita spending indicates a significant prioritisation of research investment relative to its population size.

These patterns reveal three distinct approaches to government R&D investment. First, there are the volume leaders (Egypt, Nigeria) who can leverage their larger economies to make substantial absolute investments. Second, there are the intensity leaders (Rwanda, Mauritius) who demonstrate strong relative commitment despite smaller absolute numbers. Finally, there are countries showing minimal investment across all metrics, suggesting either limited capacity or different development priorities.

The implications of these patterns are significant for scientific development and innovation capacity. Countries with sustained, substantial investment are better positioned to develop robust research infrastructure and human capital. However, the wide disparities in investment levels suggest a potential widening of the knowledge and innovation gap within Africa. The presence of countries with negligible investment raises concerns about their future competitiveness in an increasingly knowledge-based global economy. This analysis suggests the need for both increased investment in underinvesting countries and more efficient use of limited resources in countries already demonstrating commitment to R&D.

5.6.2.3 Higher Education R&D Expenditure Indicators

Nine countries surveyed the higher education sector, but results differ from country to country. Ghana either did not survey the higher education sector or did not provide data. Of the nine countries that submitted HERD data, Egypt led with almost 80% contributing to the AU's HERD. The next country was South Africa, contributing 17% of HERD. The least contributions were from Mali and Malawi. Some countries are only able to provide data on certain individual sectors or sectors other than the business sector. Data on the higher education sector plays a crucial role in national R&D systems by serving as a key driver of research and innovation. Universities and technical institutions contribute to the generation of new knowledge through basic and applied research, which underpins technological advancements and scientific discovery. Furthermore, this sector is fundamental to capacity building, as it educates and trains future researchers, scientists and skilled professionals who fuel national innovation systems. Additionally, higher education institutions often collaborate with industry and government, fostering knowledge transfer, technological development and commercialisation of research out-puts. These collaborations are essential for translating academic research into real-world applications, which supports national economic growth and industrialisation. Indicators of higher education expenditure on R&D (HERD) for the nine countries that submitted such data are presented in Table 5.28.

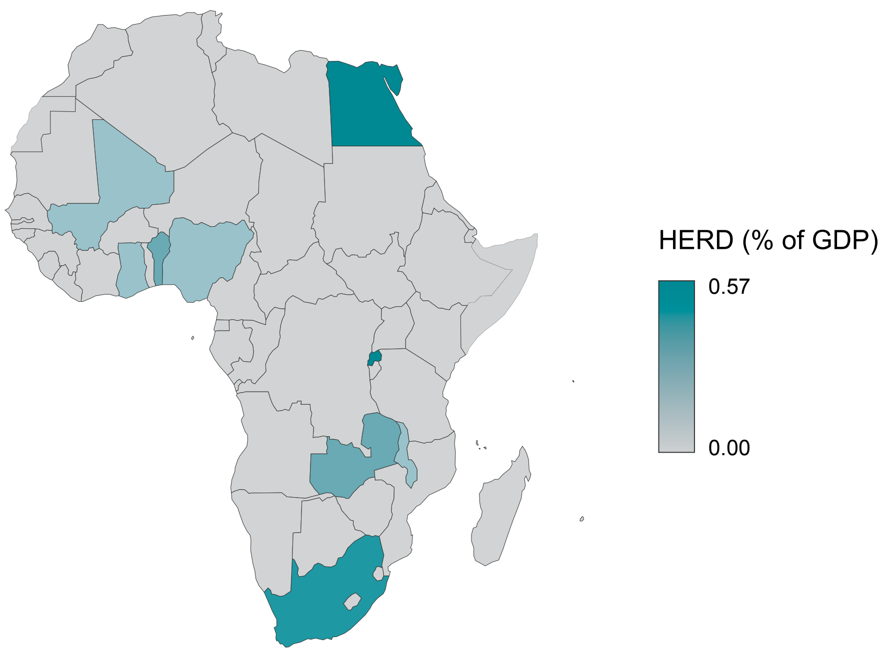
Table 5.28 Higher education expenditure on R&D, HERD based on datasets of 6 countries

Countries	HERD	HERD	HERD per capita
	(PPP$ M)	(% of GDP)	(PPP$)
Benin	47.41	0.09	3.55
Egypt	9 604.37	0.57	86.53
Malawi	26.40	0	1.40
Mali	0.02	0	0.00
Mauritius	19.80	0.06	15.69
Nigeria	137.40	0.01	0.68
Rwanda	72.57	0.396	0.04
South Africa	2 003.70	0.23	33.74
Zambia	110.47	0.14	5.52

Source: ASTI IV R&D surveys
No Expenditure data for Namibia and Senegal No HERD for Ghana

Key observations: the data reveals stark disparities in higher education research investment across African countries. Egypt demonstrates exceptional commitment with the highest values across all metrics: 9 604.37-million PPP$ in absolute terms 0.57% of GDP and 86.53 PPP$ per capita. South Africa follows as a distant second with 2 003.70-million PPP$ in absolute spending, 0.23% of GDP and 33.74 PPP$ per capita. At the other extreme, Mali shows minimal investment across all metrics, while countries like Malawi and Nigeria show exceptionally low GDP percentage allocations (0.00% and 0.01% respectively) despite varying absolute amounts.

Figure 5.13 Higher education expenditure on R&D (HERD) as a percentage of GDP for Benin, Egypt, Ghana, Malawi, Mali, Mauritius, Nigeria, Rwanda, South Africa and Zambia



Main insights: on the African continent, there are three distinct investment tiers (high, medium and low) evident in higher education investment, suggesting varying strategic orientations.

High Investment Tier:

- **Egypt:** leads across all metrics, signalling a strong prioritisation of academic research, perhaps aiming to position itself as a regional research hub. This demonstrates a strong commitment to academic research capacity, as a strategy
- **South Africa:** shows significant investment, reflecting its robust research infrastructure and emphasis on sustainable research capacity. The focus appears to be on sustainable research capacity and integration with the broader innovation system

Medium Investment Tier:

- **Rwanda:** despite having lower absolute values (translating into resource constraints), Rwanda allocates a notable percentage of its GDP (0.25%) to higher education research, demonstrating strategic prioritisation
- **Zambia:** moderately invests in higher education research (110.47-million PPP$), though its percentage of GDP is lower compared to other countries. This suggests that Zambia is in a phase of building research capacity
- **Mauritius:** while absolute investment is lower, the per capita expenditure (15.69 PPP$) is strong, emphasising focused investment relative to its small population size

Low Investment Tier:

- **Mali and Malawi:** both countries exhibit minimal investment across all metrics, indicating underdeveloped research systems, with consequent minimal research capacity
- **Nigeria:** despite being a large economy, it shows limited prioritisation of higher education research. There appears to be insufficient emphasis on building research capacity, which could hinder long-term development
- **Benin:** features moderate absolute investment but performs poorly on relative metrics, indicating early-stage development

5.6.2.4 Private Non-Profit Expenditure on R&D (PNPERD) Indicators

The third round of the ASTI programme had 12 Private Non-Profit organisations contributing to the 2019 AIO PNPERD. Of the twelve, Mali, Rwanda and South Africa are participated in this latest edition of the AIO. South Africa had the highest PNPERD at 225.2-million PPP$, despite being compared to several other countries. As a percentage of GDP, the PNPERD was quite negligible across all countries. The declining number of R&D-performing non-profit organisations (NPNs) is concerning, especially given the important role these organisations play in developing countries. Encouraging R&D activities within the private non-profit sector, regardless of the size of the organisation, could be a valuable policy for some countries in the African Union (AU). Therefore, understanding the R&D activities of NPNs should be a key component of policy considerations. Only the six countries that collected data for all sectors reported for the private non-profit sector presented in Table 5.29.

Table 5.29 Private non-profit expenditure on R&D, PNPERD

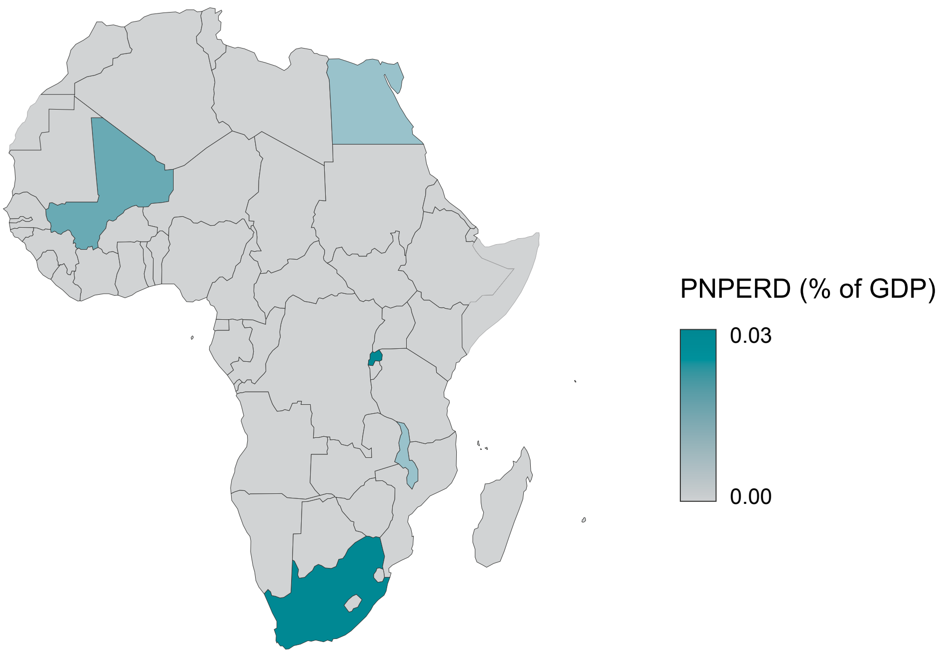
Countries	PNPERD (PPP$ M)	PNPERD (% of GDP)	PNPERD per capita (PPP$)
Egypt	4.27	0	0.04
Malawi	0.01	0	0
Mali	3.87	0.01	0.18
Mauritius	1.7	0	1.34
Rwanda	9.07	0.056	0.71
South Africa	225.2	0.03	3.79

Source: ASTI IV R&D surveys
No Expenditure data for Namibia and Senegal

Key observations: the data in Table 5.29 reveals a substantial disparity in R&D spending across various African nations. South Africa stands out with a remarkable investment of 225.20-million PPP$, far exceeding other countries in the region. Rwanda follows but at a much lower level, with 9.07-million PPP$, reflecting a significant gap in funding between the two. Egypt and Mali show moderate investment levels of 4.27-million and 3.87-million PPP$, respectively, while Malawi records the lowest R&D spending at a mere 0.01-million PPP$.

South Africa leads the data for per capita R&D spending with 3.79 PPP$, the highest among the countries analysed. Mauritius also demonstrates relatively high per capita spending at 1.34 PPP$, despite its lower absolute R&D investment. On the other end, Malawi shows almost no per capita spending on R&D, reflecting a significant disparity in investment across the countries. The variations between countries range from 0.00 to 3.79 PPP$, illustrating large differences in national prioritisation and capacity for R&D funding in this sector.

Figure 5.14. Private non-profit expenditure on R&D (PNPERD) as a percentage of GDP for Egypt, Malawi, Mali, Mauritius, Rwanda and RSA



Across most countries, the percentage of private non-profit R&D expenditure (PNPERD) as a share of GDP remains minimal (Figure 5.14), typically ranging between 0.00% and 0.01%. Only Rwanda and South Africa show slightly higher levels, reaching 0.03% of GDP.

Main insights: the data reveals a pattern of systematic underinvestment in private non-profit R&D (PNPERD) across all surveyed countries, with GDP percentages consistently remaining below 0.05%, even among relatively wealthy nations. Additionally, there is a noticeable correlation between the level of economic development and PNPERD, as more developed economies like South Africa and Mauritius demonstrate higher per capita spending on non-profit R&D. This suggests that while underinvestment in non-profit R&D is widespread, countries with greater economic resources are better positioned to allocate funds toward private non-profit research and development initiatives.

5.6.3 R&D by Type of Costs: Current and Capital Expenditure on R&D Activity

Types of costs of R&D are classified under current and capital costs. Current costs, which at least in theory, provide benefits for the current period, include labour costs for internal R&D personnel and other current costs. Current costs usually make up the largest component of the total R&D costs of any entity undertaking R&D activities.

Other current costs include costs of external R&D personnel, purchases of services and materials and other costs not elsewhere classified but are associated with the R&D performed.

Capital expenditures are incurred to generate benefits over multiple periods. They include land and buildings, machinery and equipment, capitalised computer software and other intellectual property products.

The Business sector and Private Non-Profit sector did not spend much on both current and capital costs across most countries. However, the current costs are higher than capital expenditures in the Business sector of all the countries shown. In the Government sector, Mauritius was the only country that allocated over 60% of its Gross Expenditure on Research and Development (GERD) to current expenditure, with approximately 2% designated for capital expenditure. In contrast, the Higher Education sector in Mauritius spent 69% of its Higher Education Research and Development (HERD) on capital expenditure.

Ten countries submitted data on R&D expenditure disaggregated by current and capital costs by institutional sector – or just GERD by institutional sector (Mauritius and Egypt) in Table 5.30. Data quality issues arise due to significant gaps in the dataset, marked by “n/a” or hyphens, which restrict the ability to conduct a thorough and comprehensive analysis. Additionally, inconsistencies between reported current and capital costs further complicate interpretation, highlighting the need for more standardised reporting methods across the board to ensure data accuracy and comparability.

Key observations: generally, where data is available, current costs tend to surpass capital expenditure, indicating a focus on operational costs, such as personnel, materials and ongoing project expenses

However, in certain cases, unusual trends are observed. For instance, in Nigeria’s government sector, capital expenditure (2 036.36-million) far exceeds current costs (886.25-million), suggesting a major investment in infrastructure or long-term assets. In Zambia, only capital expenditure is reported for higher education (110.47-million), which could indicate a focus on building research facilities or acquiring equipment but lacks clarity on operational spending.

Main insights: due to the paucity of data on current and capital costs, we are hesitant to make too many inferences, except to note the following.

Large gaps in data reporting suggest that countries demonstrate varying levels of capability when it comes to monitoring and recording R&D activities. This reflects the differences in institutional strength and resource allocation for such tracking, particularly in low and middle-income nations. Investment patterns generally correlate with broader economic development levels, where wealthier nations tend to show more comprehensive R&D funding.

The distribution between capital and current costs also indicates different national priorities. Some countries prioritise infrastructure development, as seen in higher capital expenditure, while others focus on maintaining operational costs, like personnel and ongoing projects.

Table 5.30 GERD by type of costs (current cost & capital expenditures) (million PPP$) of AU Member States with available datasets

Countries	BUSINESS			GOVERNMENT			HIGHER EDUCATION			PRIVATE NON-PROFIT			Total R&D expenditure
	BERD	Current cost	Capital expenditure	GOVERD	Current cost	Capital expenditure	HERD	Current cost	Capital expenditure	PNP	Current cost	Capital expenditure	
Benin	-	-	-	8.93	7.24	1.69	47.41	46.43	0.98	-	-	-	56.34
Egypt	3 311.73	n/a	n/a	4 164.36	n/a	n/a	9 604.37	n/a	n/a	4.27	n/a	n/a	17 084.73
Ghana*	35.03	22.75	12.28	58.93	53.37	5.56	-	-	-	-	-	-	93.96
Malawi	0.00	0.00	0.00	0.01	0.00	0.01	0.03	0.00	0.03	0.01	0.00	0.01	0.05
Mali	27.57	18.38	9.19	41.33	38.86	2.47	16.35	15.46	0.89	3.87	3.24	0.63	89.11
Mauritius *	3.95	n/a	n/a	79.50	n/a	n/a	19.80	n/a	n/a	1.70	n/a	n/a	104.95
Nigeria	-	-	-	2 922.61	886.25	2 036.36	137.40	118.79	18.61	-	-	-	3 060.01
Rwanda	11.08	9.02	2.05	129.66	81.14	48.53	72.57	45.67	26.90	9.07	6.25	2.82	222.38
South Africa	1 904.45	1 643.84	260.61	1 242.69	1 119.87	122.82	2 003.70	1 890.96	112.74	225.20	213.86	11.34	5 376.04
Zambia	-	-	-	0.02	-	-	110.47	-	110.47	-	-	-	110.49

(*) Incomplete coverage with less than four R&D performing sectors or missing data | (-) Sector not covered or missing breakdown
Namibia and Senegal did not provide expenditure data | Incomplete GERD: Benin, Ghana, Nigeria, Senegal

5.6.4 Conclusion, Challenges and Recommendations

The conclusions and recommendations form an integral part of this report in conformity with the data submitted by countries where unique challenges were identified and action to be taken.

The R&D profiles shown in the current report indicate that few countries are dedicated in embracing R&D indicators as a guide to understanding their scientific, technological, social and economic dynamics. Some countries are surging ahead with the development and improvement of their STI system, in particular South Africa and Egypt. However, these two countries have, to some extent, developed infrastructure facilities and financial support to measure and evaluate their STI systems than other African countries in this report. This begs for a call for the AU to strengthen efforts to support R&D to grow and enhance their STI activities. The investment in R&D in the Business sector was low or non-existent in African countries. This suggests a reliance on the public sector R&D, mainly from higher education, to drive research and development efforts. The observations may well be true; however, caution should be exercised when interpreting the results because, firstly, the sample size was very low, secondly, at the same time, the average size of firms in different countries differs.

The R&D measurement is still considered relatively new, as it is not a common practice in many developing countries, in majority least developed countries (LDCs). The information gleaned from R&D statistics should contribute to the general knowledge produced from measuring STI in its entirety. In the case of R&D measurement in the AU, indicators should provide a description of problems and or successes common among countries. That is, the measurements should allow the R&D indicators to be disaggregated to a level at which R&D characteristics are relevant to the country and internationally comparable. This may be difficult to achieve given the paucity of results from some countries because of a lack of resources for data collection and in some cases, data is not available.

As far as ASTII Phase 4 is concerned, Covid-19 affected the momentum causing the first ever decline in the ASTII programme. This is of concern to the AU and individual governments because these limits robust assessments of the stages of development as seen through STI.

The varying distributions of types of R&D expenditures formed the basis of much of the analysis in this chapter on the country data, as it pertains to industrialisation. The distributions reveal fundamental differences in national research strategies and development priorities. Rwanda's high investment in basic research suggests a long-term commitment to building fundamental scientific knowledge and capabilities, potentially positioning itself for future scientific breakthroughs and innovations. This approach contrasts sharply with Mauritius and Mali, where the heavy focus on applied research indicates a more immediate, solution-oriented research strategy aimed at addressing current technological and challenges, such as maintaining high-tech equipment or broader developmental challenges.

These patterns may reflect dissimilar stages of scientific development and varying national priorities. Countries with higher proportions of experimental development, such as Mali at 31.95%, may be more focused on translating research into practical applications and commercial products. The more balanced distribution seen in South Africa and Malawi might indicate more mature research ecosystems that can sustain activities across the entire research spectrum, from fundamental science to practical applications.

The implications of these distributions are significant for long-term scientific capacity and economic development. Countries with extremely low basic research investment, like Mali, might face challenges in developing independent scientific capabilities and may remain dependent on importing fundamental knowledge. Conversely, countries maintaining substantial basic research activities, like Rwanda and South Africa, are better positioned to contribute to global scientific knowledge and develop innovative solutions to local challenges. The high focus on applied research in most countries suggests a pragmatic approach to R&D, prioritising research with clear practical applications, which might be more aligned with immediate developmental needs but could potentially limit breakthrough innovations that often emerge from basic research.

5.6.4.1 African R&D Systems and Their Funding Models

Specific archetypes emerge from the country data on funding of R&D. First, developed countries tend to have their Business sectors dominating. In contrast, developing economies do not. This may be seen from calculating BERD/GERD for the countries in the OECD (2024) Main Science and Technology Indicators (MSTI). The countries in Africa reporting GERD and BERD all have BERD/GERD ratios less than 50%. By analysing government funding data for R&D across African countries, it's possible to group nations into categories based on similar funding structures. However, one notable absence in this classification would then be the dominance of the Business sector in funding R&D, a profile that has not yet emerged in any African nation. Even though Egypt and South Africa are the most advanced in this regard and may be on a developmental trajectory towards such a profile, they are not yet at the stage where the private sector outpaces government contributions to R&D. See Table 5.31 for a summary synthesis of the analysis conducted in the body of this chapter.

Table 5.31 Funding model archetypes, countries, their characteristics, strengths and challenges

Funding model	Countries	Key characteristics	Strengths	Challenges
Government-centric	Mauritius, Egypt, Rwanda, Nigeria (based on significant government expenditure and GDP percentage in figure 5.8	High government funding (>60% of total R&D)	Strong state commitment, consistent funding	Limited private sector engagement
Diversified	Mali, South Africa	Balanced funding from multiple sources.	Resilient funding ecosystem, relatively strong private sector	Maintaining balance between sources
Aid-dependent	Malawi, Benin dDue to low government funding and reliance on external sources (figure 5.8.). Ghana (similar pattern to Benin, with limited government funding suggesting external dependency	High external funding dependency	International partnerships	Limited domestic resource mobilisation
Underdeveloped	Zambia	Minimal R&D investment	Potential for growth	Needs fundamental system development

5.6.4.2 Main challenges

The first ever decline in countries participating in the ASTII programme after Covid-19 with lockdown affecting the momentum in data collection and face-to-face interviews of statistical units. In 2007, with the launch of the ASTII initiative in Mozambique (Maputo, 17-18 September 2007), the African Intergovernmental Committee on STI indicators represented by Member States mainly involved in the African Peer Review Mechanism (APRM) committed in the awareness process because of the lack of S&T information among African countries".

In 2023, only a limited number of countries are seen actively participating in the initiative. Some of these countries have incomplete datasets or have not compiled their data correctly. This challenge may be attributed to the high turnover of ASTII experts at the national level, insufficient national budgets to support ongoing surveys in certain

5.6.4.3 Recommendations

Considering that the submission of data by AU member countries decreased from 23 countries in the previous report (AIO-3) to only 12 countries with R&D personnel datasets among which 10 with R&D expenditures in the current AIO-4 edition, namely: Benin, Egypt, Ghana, Malawi, Mali, Mauritius, Nigeria, Rwanda, Republic of South Africa and Zambia;

Cognisant that six countries (Egypt, Malawi, Mali, Mauritius, Rwanda and South Africa) submitted the full dataset in all sectors (business, government, higher education and private non-profit); four countries submitted data in two sectors (Benin, Nigeria and Zambia in government and higher education; and Ghana in business and government sectors).

Looking at the high concentration of R&D personnel and its sub-category researchers in government and higher education sectors for all the countries, as well as the female R&D personnel and female researchers in the two sectors; and

Based on the limited analysis of age distribution justified by the lack of data from some counties not helping in addressing the existing gaps in critical areas of R&D, even though information on female R&D personnel and female researcher were less than their male counterparts in all areas of R&D activities.

Noting some implications such as:

- **The link between economic development and R&D investment justified** stronger economies demonstrating higher absolute R&D expenditure capacity
- **The sectoral balance biased by** the over-reliance on government funding, requiring stimulating private sector and PNP engagement
- **The international funding considerations requiring national strategies** to address high dependency on foreign funding to ensure sustainable funding in integrating international funding with national priorities and building domestic funding capacity
- **The research system as part of a robust national innovation system** affecting resource-constrained countries to prioritise building basic research capacity
- **The strategic investment priorities for** balanced investment across R&D sectors and strengthened higher education research capacity to encourage greater private sector participation

The ASTII technical advisory group and the drafting team recommend the following:

1) To develop a strategy to encourage member countries to submit R&D datasets as scheduled and RECs to accompany AUDA-NEPAD and AOSTI's effort in coordinating the ASTII programme
2) To make all R&D personnel variables mandatory: age, sex, qualification, occupation, field of R&D and FTE
3) To prioritise the harmonisation of the reference period to enable comparison among the member countries
4) To make a follow-up on how countries are progressing in the implementation of the ASTII programme
5) To provide updated R&D dataset on expenditures across all four Frascati institutional sectors to AUDA-NEPAD
6) To provide the necessary R&D disaggregated information on expenditures to AUDA-NEPAD
7) To consistently conduct national R&D surveys with committed fundings for an annual or biannual data collection
8) To encourage and incentivise the adoption of standardised methodologies and to collaborate on shared learning experiences related to the Frascati methodology in R&D surveys
9) To build a community of practice among countries, with champions
10) To discuss the commonalities among countries collecting not only R&D statistics but STI in general, with STI officials or national experts through local, regional and international dialogues.

Member States:

11) **To tailor funding strategies to the specific needs of different national R&D systems to enhance participation and sustainability:**

    (a) For government-dominated systems: to incentivise private sector participation, develop industry-academia partnerships and create research commercialisation pathways

    (b) For diversified systems: to further strengthen business participation, maintain government support and enhance research commercialisation

    (c) For aid-dependent systems: to build sustainable domestic funding sources, strengthening government and business participation, and developing long-term research capacity

    (d) For underdeveloped systems: to build basic research infrastructure, establish partnerships with more advanced research systems and create foundational funding mechanisms to support long-term growth

12) **To actively participate in the development and establishment of regional research networks and centre of** excellence in STI measurement redistribute the workload between AUDA-NEPAD/ASTII, AOSTI and RECs as part of a **regional collaboration and knowledge exchange set-up.**

    The outcome will:

    - Address the concerns about a widening knowledge and innovation gap across the continent exacerbated by the significant disparities among African nations, particularly in the correlation between a country's GDP and its expenditure on Gross Expenditure on R&D (GERD)
    - Encourage the sharing of data infrastructure to overcome individual resource constraints and enhance international partnerships to build and enhance research capacity, foster collaboration and share expertise across borders

Finally, AUDA-NEPAD (Office of Science, Technology and Innovation) and RECs:

13) **To jointly strengthen funding mechanisms and survey continuity:** establish dedicated budget lines and multi-year funding commitments for R&D surveys within national statistics offices. Implement cost-sharing arrangements across relevant ministries and mandate regular survey cycles through national legislation. Additionally, create permanent R&D statistics units and develop standardised digital infrastructure for efficient data collection and processing

14) **To jointly standardise R&D survey methodology and build capacity:** adopt the Frascati Manual as the standard across Africa, develop simplified guidelines for new countries and create standardised survey tools in multiple languages. Establish regional training centres, mentor partnerships and online learning platforms to build capacity for effective R&D surveys

15) To jointly enhance regional coordination through the AU Specialised Technical Group on Education and STI statistics or REC Reference group on STI statistics to update ministers

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CHAPTER 6
INNOVATION & EMERGING MEASUREMENT ISSUES

6.1 INTRODUCTION

There is sufficient evidence, globally, linking innovation to economic growth, competitiveness and better quality of life as it is a potential creator of wealth and well-being. In Africa, innovation can help achieve the Sustainable Development Goals (SDGs) by 2030 and strengthen economies by creating jobs for the continent's young population. Viewed from the enterprise perspective in developed economies, innovation is seen as a way to increase sales by introducing new or improved goods and/or services and developing new industries, in developing economies. However, it may be predominantly seen as a strategy for survival. Evidence in the literature shows that in the manufacturing and services sectors, as a firm's innovation performance increases, so does its business performance and growth, potentially leading to competitiveness.

The literature also suggests that innovative firms are likely to be more oriented to exporting their goods and services than non-innovative firms (Mohnen and Therrien, 2003; Mansury and Love, 2008).

On a global scale, examples of the documentation of the importance of innovation include the Innovation Strategy of the OECD and the focus of the European Commission on Innovation and the Innovation Union (OECD, 2012; European Commission, 2011).

Policymakers and business leaders have recognised and accepted these potential benefits of innovation.

Governments intervene when economic systems or market information fail to provide the evidence necessary for fostering innovation and they develop strategies to guide this intervention. Examples of innovation strategies at a global level are available in the Organisation for Economic Cooperation and Development (OECD, 2010) and the European Union (EU) (CEC, 2006, 2009).

Once a government has developed an innovation strategy, statistical measures are required to monitor the progress of specific interventions and to support evaluation. Policy learning occurs mainly through such evaluation, leading to improvement of the intervention or its abandonment if it is found to be ineffective. If innovation is identified as economically and socially important and it is the subject of government policy, then statistical measures, leading to indicators, are steps towards providing evidence for policy development to ensure a better environment for innovation.

Several African countries are taking part in building the human and institutional capacities needed to produce common internationally comparable indicators and conducting surveys of research and innovation at national levels, to measure their innovation activities through ASTII (AU-NEPAD, 2010).

This chapter presents the status of innovation performance and emerging issues in Africa. The chapter begins by reviewing innovation policies in some African countries. Next, the chapter presents innovation performance in Africa as measured using the Global Innovation Index (GII). It presents the status of innovation performance in the business sector, mainly focusing on manufacturing and services firms from three African countries during the period 2019-2021. On emerging issues on innovation in Africa, the chapter covers the following topics: measuring innovation in government, measuring innovation in the higher education sector and measuring innovation in the informal business sector.

6.2 INNOVATION PERFORMANCE IN AFRICA[21]: THE GLOBAL INNOVATION INDEX ASSESSMENT AND AFRICA'S INDUSTRIALISATION READINESS

6.2.1 Background

Over the past two decades, the Global Innovation Index (GII) has been referred to as a policy instrument to inform evidence-based policymaking. About 80 GII indicators deal with the framework conditions that prepare the way for innovation. This chapter is about the GII indicators and their assessment of the innovation performance of African economies in the context of Africa's industrialisation, while helping stakeholders to gain insights into the progress and health of the innovation ecosystems on the continent. With implications for both innovation measurement and policy, the chapter examines four indicators that can influence Africa's industrialisation drive in the face of uncertainties. The Global Innovation Index (GII) was launched in 2007 to provide a comprehensive depiction of innovation in society. In its 16th edition as of 2023, the GII continually evaluates innovation factors, serving as a crucial tool for decision-makers and offering a detailed metric database for refining innovation policies.

Science, Technology and Innovation (STI) are key to building resilient economies in a world faced with uncertainties, such as climate change and the attendant environmental challenges and the Covid-19 pandemic and its aftermath. Other challenges include the Digital Age and Deep Science innovation waves and their applications, population growth and urbanisation and geopolitical conflicts. These global challenges are reflected in several development agendas including Agenda 2063 (AU, 2014); Science Technology and Innovation Strategy for Africa 2015-2024 (STISA 2024) now STISA-2034; the STI for Sustainable Development Goals (SDGs) Roadmaps (SDG.2021); the 10-year Africa Union – European Union Innovation Agenda from 2023 to 2032 (AUC and EC, 2023); The African Development Bank's Outlook (AfDB, 2017).

To be competitive, Africa must overcome the above-stated challenges, particularly SDG 9, to build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation. To this end, several African countries have recently adopted industrial. investment. and innovation policy frameworks to promote the industrialisation of their economies (Mugabe and Manyuchi, 2023). Consequently, the African Union (AU) has urged members countries to adopt the use of the Intellectual Property (IP) System to drive industrialisation, promote innovation and entrepreneurship development, enhance beneficiation and value addition in collaboration with the private sector and regularly collect evidence on intra-Africa trade including the informal economy (C10.2018).

Since the launch of the Global Innovation Index (GII) in 2007, several policymakers in Africa and beyond have referred to the GII as part of their economic policy strategies and processes. At the international level, the GII was recognised by the United Nations Economic and Social Council in its 2019 resolution on STI for development as a critical benchmark for measuring innovation in relation to SDGs (UN, 2019). Equally, the meeting of the Southern African Development Community (SADC) Ministers for Education, Science, Technology and Innovation called on their Member States to use the GII to enable the alignment of their STI strategies to the SADC protocol (SADC, 2023).

Following the introductory remarks, the rest of this section is organised as follows: the next sub-section introduces the structure of the GII model and its components. It presents the conceptual framework for the computation of the 80 or so indicators that lead to the index. It highlights the processes of data collection/coverage, collation and points to areas that need improvement in terms of data quality. The section that follows deals with the actual assessments of the innovation performance of African economies by presenting their scores and ranks. Section four examines four indicators that can influence the trajectory of Africa's industrialisation in the face of obvious uncertainties. The standard definitions are reiterated and the scores and ranks are analysed in the context of African development frameworks, such as Agenda 2063 and STISA 2024. The final section offers recommendations on using the Gender Inequality Index (GII) as a tool

21 This section draws from the authors' (Rivera Leon Lorena, Wunsch-Vincent Sacha) previous work in the Global Innovation Index 2023, published in September 2023, particularly the technical annexes to the report.

for policy learning and emphasises the importance of local ownership. The section concludes with the GII as a strategic tool for action, specifically to measure and compare the innovation performance of African economies and support their industrialisation drive.

6.2.2 Methodology: Conceptual Framework for Data Sourcing and Handling

The GII, initially an innovation ranking approach, has evolved over the past years into a “family” of tools supporting countries in their innovation journey. This includes a ranking of the world’s top Science and Technology clusters (cities and agglomerations with the most innovative activity), the Global Innovation Tracker illustrating recent trends in innovation investments and measuring technological progress and adoption and the GII theme, providing in-depth analyses into relevant innovation topics every two years.

The GII ranking unveils the world’s innovation leaders’ assessment of the innovation performance of over 130 economies. It is an input-output statistical model that follows the OECD Handbook on Constructing Composite Indicators (OECD et al, 2008). As shown in Figure 6.1, Table 6.1a, the overall Global Innovation Index (GII) ranking is determined by two equally important sub-indices: the Innovation Input Sub-Index and the Innovation Output Sub-Index. The overall GII score is calculated as the average of these Input and Output Sub-Indices, from which the rankings of GII economies are generated.

While the GII ultimately produces a ranking, its main goal is to enhance the path to precise measurement, comprehension of innovation and identification of effective policies and practices. The extensive data metrics at the index, sub-index or indicator level enable ongoing performance monitoring and benchmarking against economies in the same region or income group.

In 2023, the GII model included 80 indicators, which fall into three categories:

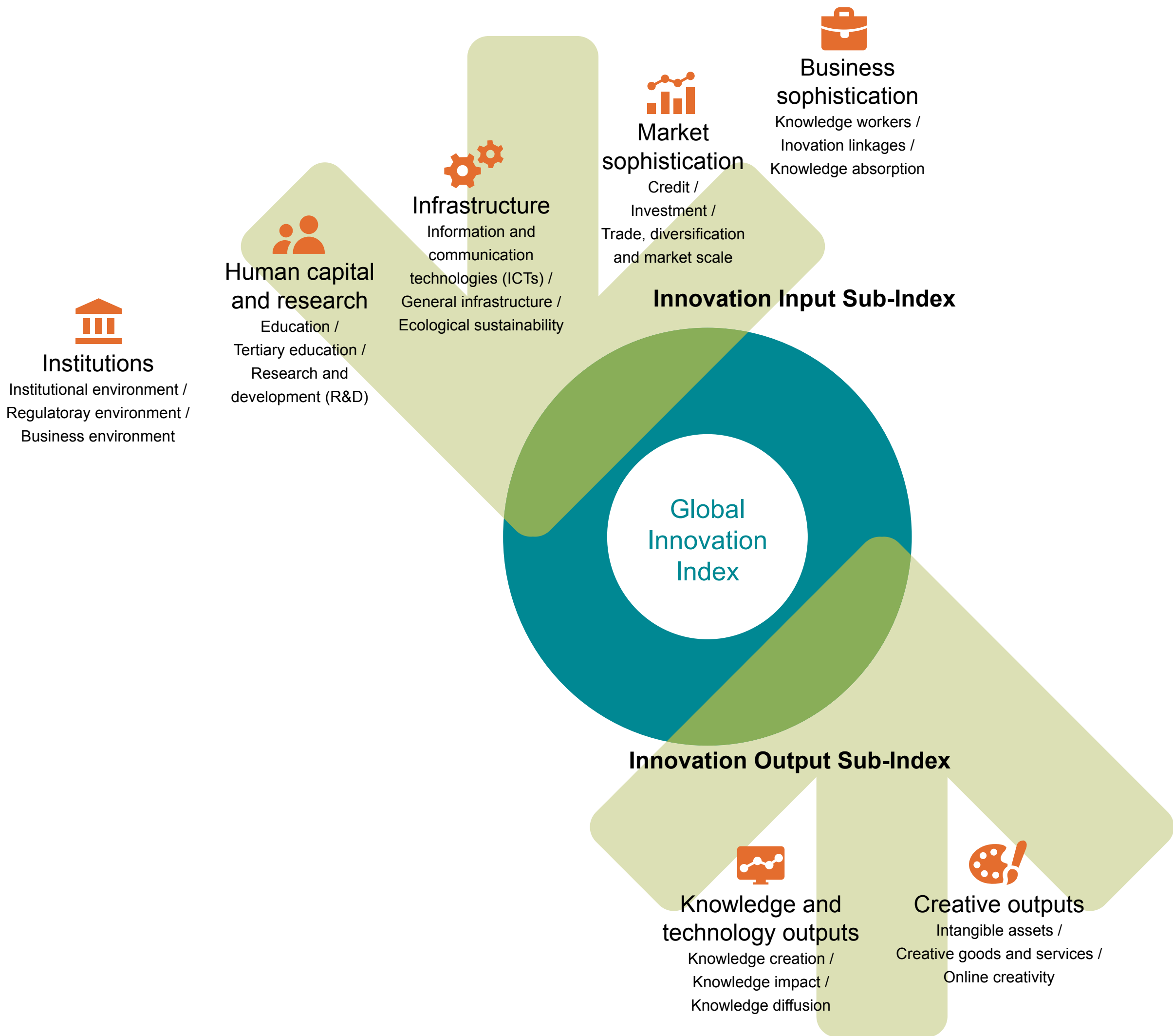
- Quantitative/objective/hard data (64 indicators)
- Composite indicators/index data (11 indicators)
- Survey/qualitative/subjective/soft data (5 indicators)

The data is collected annually from both public and private sources. The vast majority of GII data is not collected from its Member States directly by WIPO. WIPO utilises data provided by various economies to global organisations responsible for specific data collection, such as the UNESCO Institute for Statistics (UIS) for information related to R&D. The sole exception is the intellectual property data that WIPO collects annually from Member States[22]. Public sources are mainly international organisations such as the UIS, the International Labour Organization (ILO), the World Bank and the World Trade Organization (WTO). Private sources are used when public sources are not available to measure some specific innovation-related activities, such as venture capital, unicorn companies, the availability of intangible assets (e.g. the value of brands) or the creation of mobile apps[23].

22 See www.wipo.int/ipstats

23 For a comprehensive list of data sources and definitions, see: https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023-appendix3-en-appendix-iii-global-innovation-index-2023.pdf

Figure 6.1 Conceptual framework of the Global Innovation Index 2023



Source: Global Innovation Index Database, WIPO, 2024.

6.2.3 Scope and Relevance

One of the main limitations of the GII rankings is their comparability over time. Each ranking reflects the relative position of a particular economy based on the conceptual framework, data coverage and sample of economies of a specific GII edition. It also reflects changes in the underlying indicators at source and data availability[24].

Despite this, for many years, governments around the world have successfully used the GII to improve their economies' innovation performance and shape evidence-based innovation policies[25]. One major benefit of the GII is that it puts

24 Several factors influence the year-on-year rankings of an economy: the actual performance of the economy in question; adjustments made to the GII framework (changes in indicator composition and measurement revisions); data updates, the treatment of outliers and missing values; and the inclusion or exclusion of economies in the sample.

25 A survey carried out by WIPO in 2022 showed 70 percent of WIPO Member States were using the GII to improve innovation ecosystems and metrics, as well as it being a benchmark for national innovation policies or economic strategies.

evidence and metrics at the core of conceiving, deploying and evaluating innovation policies. In countries where GII is actively used for policymaking, Statisticians, innovation actors and policymakers work together to understand the country's innovation performance, based on the GII metrics. Often, the policy discussion shifts towards leveraging domestic innovation opportunities while addressing country-specific weaknesses. Both steps require coordination among various public and private innovation actors, along with government entities.

Today, the GII has become a catalyst for the national collection of innovation indicators. Economies now have an interest in ensuring the GII can rely on the complete and updated innovation metrics they provide. Indeed, there is increasing interest among countries in building sub-national innovation indices at the regional or city level that mirror the GII framework or comprise selected GII indicators (WIPO, 2023).

For the sake of transparency and replicability of results, missing values are not estimated in the GII. However, for an economy to feature in the GII, it must fulfil the minimum symmetric data coverage criteria (DMC). Each economy must have available data for at least 66% of all indicators in the Innovation Input Sub-Index and at least 66% of all indicators in the Innovation Output Sub-Index. In 2023, this corresponded to 36 available input indicators and 18 Output indicators. In addition. all economies should also have scores for at least two sub-pillars per pillar. In the GII 2023, 132 economies had sufficient data available to be included in the Index. A total of 61 economies did not make it into the GII 2023 due to a lack of available data. For each economy. only the most recent yearly data were considered. As a rule, the GII indicators consider data from as far back as 10 years earlier, relative to the reporting year (e.g. for the GII 2023, data from as far back as 2013 was considered).

Twenty-two out of the sixty-four economies excluded (34% of the total) from the GII 2023 Edition because of missing data were African economies. The Democratic Republic of Congo, Lesotho, Seychelles and Chad did not pass the DMC criteria in Innovation Outputs. Even if they had enough innovation input data. Conversely, Malawi, Congo, and Sudan did not have enough innovation input indicators. Figure 6.2a Table 6.1a gives details on these twenty-two African economies.

Table 6.1a African economies not included in the GII 2023 because of lack of data

ISO3	ECONOMY NAME	Region	Subregion	Income Group	Innovation Inputs	Innovation Outputs
CAF	Central African Republic	SSA	Middle Africa	LI	46%	62%
COD	Democratic Republic of the Congo	SSA	Middle Africa	LI	46%	63%
COG	Congo	SSA	Middle Africa	LM	61%	77%
COM	Comoros	SSA	Eastern Africa	LM	57%	62%
DJI	Djibouti	SSA	Eastern Africa	LM	48%	50%
ERI	Eritrea	SSA	Eastern Africa	UM	56%	65%
GAB	Gabon	SSA	Middle Africa	UM	40%	63%
GMB	Gambia	SSA	Western Africa	LI	59%	54%
GNB	Guinea-Bissau	SSA	Western Africa	LI	44%	62%
GNQ	Equatorial Guinea	SSA	Middle Africa	UM	46%	62%
LBR	Liberia	SSA	Western Africa	LI	48%	50%
LBY	Libya	NAWA	Northern Africa	UM	74%	76%
LSO	Lesotho	SSA	Southern Africa	LM	74%	62%
MWI	Malawi	SSA	Eastern Africa	LI	63%	69%
SDN	Sudan	NAWA	Northern Africa	LI	61%	49%
SLE	Sierra Leone	SSA	Western Africa	LI	43%	31%
SOM	Somalia	SSA	Eastern Africa	LI	42%	31%
SSD	South Sudan	SSA	Eastern Africa	LI	43%	27%
STP	São Tomé and Principe	SSA	Middle Africa	LM	50%	50%
SWZ	Eswatini	SSA	Southern Africa	LM	63%	62%
SYC	Seychelles	SSA	Eastern Africa	HI	76%	62%
TCD	Chad	SSA	Middle Africa	LI	60%	62%

Source: Global Innovation Index Database, WIPO, 2023.
Notes: SSA: Sub-Saharan Africa, NAWA : Northern Africa and Western Asia, LI : Low Income,
LM : Lower Middle-Income | UM : Upper Middle-Income | HI : High-Income

6.2.4 Innovation Performance of African Economies

A total of 32 African economies are covered in the GII 2023 (see Table 6.1b Figure 6.2b for details). Only Mauritius (57th) and South Africa (59th) rank among the top 60, with South Africa entering this group having gained two ranks since 2022. Nine additional African economies rank within the top 100 globally, namely: Morocco (70th), Tunisia (79th), Botswana (85th), Egypt (86th), Cabo Verde (91st) – making a comeback to the Global Innovation Index (GII) in 2023 – Senegal (93rd), Namibia (96th), Ghana (99th) and Kenya (100th). Furthermore, 10 African economies improved their GII ranking in 2023, including South Africa, Botswana, Egypt, Senegal, Rwanda (103rd), Togo (114th), Benin (120th), Mauritania (127th) and Guinea (128th).

Mauritius ranks highest within Africa in institutions (26th) and market sophistication (24th). It leads worldwide in venture capital investors (1st) and ranks 5th in venture capital received. Cabo Verde ranks first in the region for infrastructure (64th) and performs well in indicators such as gross capital formation (3rd), expenditure on education (13th) and

FDI inflows (17th). Botswana tops in business sophistication (56th) and performs well in loans from microfinance institutions (12th).

Tunisia heads Africa in knowledge and technology outputs (50th). thanks to its good performance in scientific and technical articles (10th) and high-tech exports (40th). South Africa is second on the continent, with high rankings in software spending (28th), patents by origin (34th) and PCT patents (40th).

In 2023, Senegal improved its ranking by six places, now standing at 93rd. This notable enhancement can be attributed to its performance in knowledge and technology outputs, where it ranks 63rd. Additionally, Senegal ranks first in the world for the valuation of its unicorn company, Wave (a fintech firm), sharing this top position with high-income economies such as Estonia, Israel, Lithuania and the United States. Other strong points include gross capital formation (8th), loans from microfinance institutions (10th), foreign direct investment inflows (13th) and venture capital received (19th).

In the GII 2023, 21 economies outperformed expectations in innovation relative to their level of economic development (see Figures 6.2 and 6.3). Among these, seven are African nations: South Africa (59th), Morocco (70th), Tunisia (79th), Senegal (93rd), Rwanda (103rd), Madagascar (107th) and Burundi (130th) (Table 6.1b). Africa has the highest number of overperformers in the world.

Conversely, 10 African economies perform below expectations based on their level of development, highlighting the disparities in innovation performance across the region. These countries include Botswana (85th), Côte d'Ivoire (112th), Algeria (119th), Benin (120th), Cameroon (123rd), Ethiopia (125th), Mauritania (127th), Guinea (128th), Mali (129th) and Angola (132nd). In 2023, Senegal made a return to the group of overperformers, having last held this status in 2017. Egypt (86th), Namibia (96th), Nigeria (109th) and Zambia (118th) also showed notable improvements this year, changing their status from below expectations to meeting expectations for their level of development.

Morocco, Tunisia, Madagascar and Zimbabwe are efficient at converting innovation inputs into outputs (Figure 6.2b).

Table 6.1b GII 2023 rankings overall and by innovation pillar. 2023

Economy	Overall GII	Institutions	Human capital and research	Infrastructure	Market sophistication	Business sophistication	Knowledge and technology outputs	Creative outputs
Mauritius	57	26	64	74	24	91	90	57
South Africa	59	88	84	68	45	61	56	63
Morocco	70	83	86	94	80	107	65	55
Tunisia	79	107	46	89	98	119	50	50
Botswana	85	37	73	85	70	56	117	106
Egypt	86	103	95	90	88	100	77	73
Cabo Verde	91	44	97	64	96	65	98	108
Senegal	93	59	107	98	81	122	63	113
Namibia	96	50	76	100	84	99	123	114
Ghana	99	93	105	105	117	83	111	71
Kenya	100	84	118	107	108	84	81	95
Rwanda	103	33	94	101	115	109	100	117
Madagascar	107	121	102	131	113	123	121	62
Nigeria	109	115	80	123	127	82	124	84
Côte d'Ivoire	112	71	128	106	123	96	118	97
United Republic of Tanzania	113	73	126	115	83	105	119	120
Togo	114	102	111	117	111	111	108	105
Zimbabwe	117	130	104	119	121	112	113	86
Zambia	118	119	93	111	110	98	130	112
Algeria	119	97	113	102	125	120	128	107
Benin	120	58	114	114	118	111	116	129
Uganda	121	64	124	116	128	118	105	122
Cameroon	123	91	112	130	129	88	104	118
Burkina Faso	124	92	108	121	116	128	112	130
Ethiopia	125	116	131	132	114	130	84	126
Mozambique	126	129	116	103	122	129	127	115
Mauritania	127	89	119	124	130	108	115	131
Guinea	128	98	132	127	132	127	125	110
Mali	129	117	121	128	126	115	120	128
Burundi	130	106	100	126	131	121	131	125
Niger	131	94	130	125	120	116	129	132
Angola	132	118	127	129	119	132	132	121

Source: Global Innovation Index Database. WIPO. 2023. – Performing above expectation for level of development

Figure 6.2a Innovation overperformers relative to their economic development

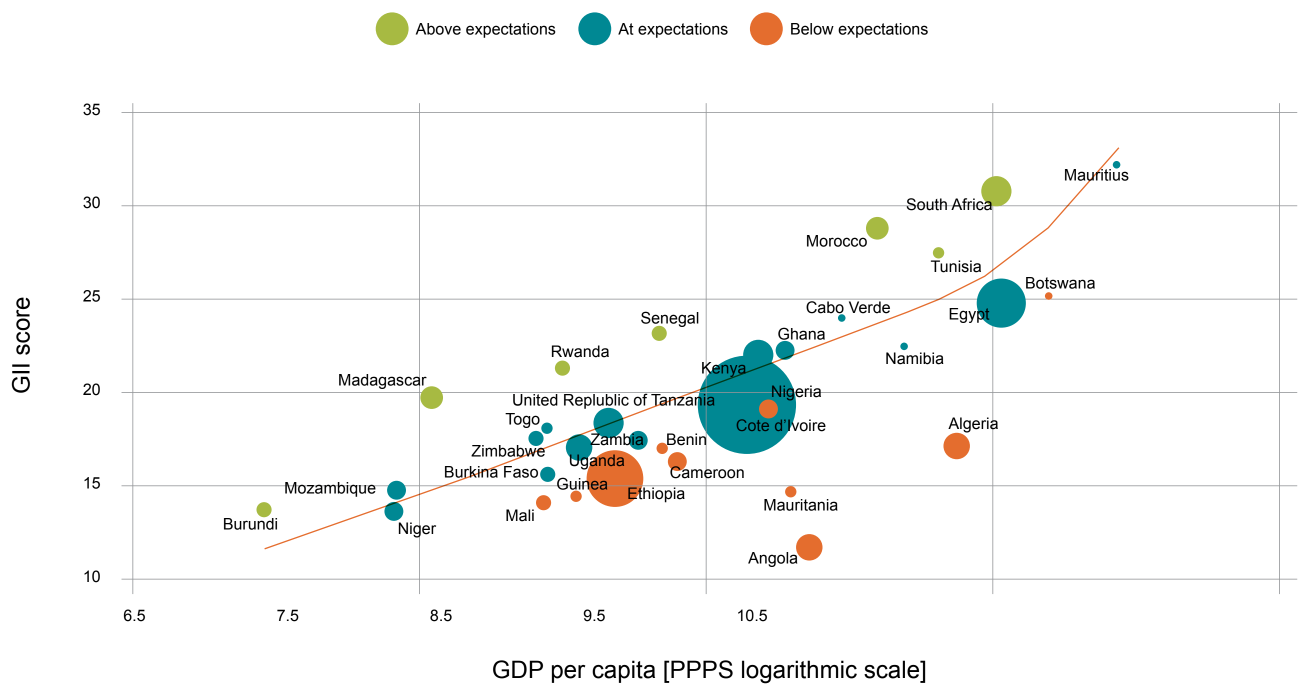
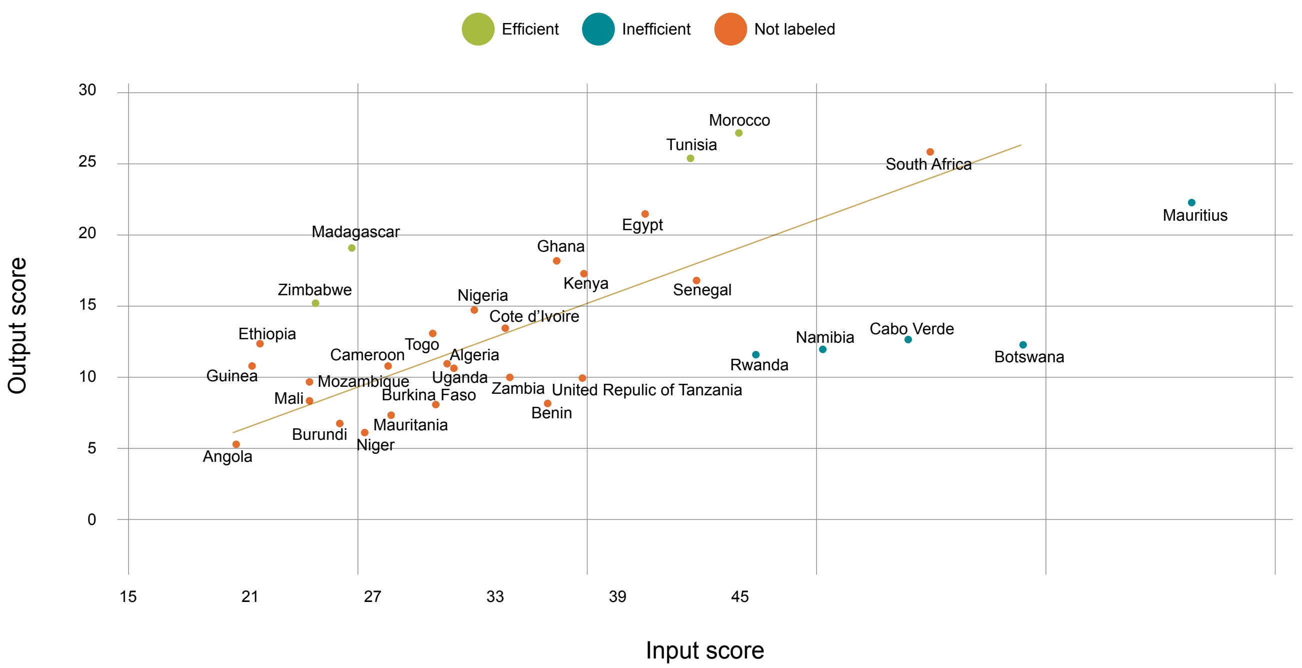


Figure 6.2b Innovation input to output performance. 2023 | Global Innovation Index Database. WIPO. 2023.



6.2.5 Industrialisation Indicators and the AU Agenda 2063

Africa must industrialise to fulfil its economic potential, as it has become an investment destination thanks to its abundant resources, demographic trends, infrastructure development, policy reform and technological advancement. As the Information and Communication Technology (ICT) has revolutionised the banking industry by expanding access to financial services and enhancing the overall customer experience, likewise the dynamics of the fourth industrial revolution (IPV4) have the potential for Africa to leapfrog and transform traditional industries and societies through incremental and disruptive innovation (AfDB. 2017).

In this section, we singled out four GII indicators[26] to track Africa's industrialisation readiness. The ASTII surveys use the International Standard Industrial Classification of All Economic Activities (ISIC., Rev4) to collate R&D and Innovation data. It is therefore the right vehicle to determine the relevant ISIC sub-categories at which the four identified indicators shall be assessed to inform the industrialisation readiness. These indicators include Domestic Industry Diversification; the percentage of High-Tech and Medium-high-tech Manufacturing in total manufacturing output; production and export complexity; High-Tech imports as a percentage of total trade; and High-Tech exports as a percentage of total trade.

Domestic industry diversification. Domestic industry diversification is an indicator that measures the concentration and the extent to which a country's industry system is diversified across different industrial subsectors. A diversified domestic industry leads to the creation of a variety of jobs, promotes technology transfer and knowledge exchange, calls for optimal resource allocation and utilisation and ultimately triggers innovation. There is also evidence showing that more diverse economies perform better at innovation overall (Cornell University et al, 2018). A country with a perfectly diversified industrial system will have an indicator value close to zero, whereas a country active in only one industrial subsector will have a value of one (least diversified). In the GII 2023 report, African economies were the least diversified economies worldwide, with an average diversification index of 0.35 in 2020. In that year (2020), the most diversified African economy was Botswana with a diversification index of 0.20, while the least diversified economy was Burundi (0.80), The Domestic industry diversification indicator provides evidence to inform the attainment of Goal 4 of the AU Agenda 2063 namely "*Transformed economies and job creation*" and the 7th Aspiration of Agenda 2063. i.e. *making Africa influence global policy issues*. On the same note, monitoring and evaluation of these components are necessary steps to assess industrialisation readiness.

High-tech and medium-high-tech manufacturing as a percentage of the total manufacturing output. This indicator is a measure reflecting the proportion of a country's manufacturing activities that involve the production of technologically advanced products. High-tech manufacturing plays a crucial role in industrialisation as it typically involves the use of advanced technologies, cutting-edge processes and sophisticated inputs.The advent of the fourth industrial revolution and the Continental Free Trade Agreement are two priority programmes in the Agenda 2063, among many that would benefit from evidence generated by this indicator.

Data from the GII 2023 shows that Morocco holds the highest share of high-tech manufacturing in total manufacturing output among African economies (42.8% in 2019), followed by Tunisia (24.3% in 2019) and South Africa (23.4% in 2016).[27] On average, African economies have the lowest share of high-tech manufacturing worldwide (9.9% in 2020), followed by Central and Southern Asia (11% in 2020) and Western Asia (28.2% in 2021). Over time, data collated by the ASTII programme could serve as a vehicle to assess progress and readiness in a relevant grouping as categorised in ISIC. Rev4. The latter includes the transformation of traditional industries, the penetration of advanced technologies and how they enhance efficiency, productivity. and innovation.

26 These indicators are selected based on their manufacturing and industrialisation contents. For more information on the title, description, definition and source for these indicators, refer to Appendix III of the Global Innovation Index 2023 Report.

27 Data availability for African economies in this indicator is low. Although most economies covered in the GII have data for 2020 for this indicator, out of the 21 African economies that have data for this indicator in the period 2013-2020, only 5 African economies have data for 2020.

Production and export complexity. The production and export complexity of an economy is measured by the Economic Complexity Index (ECI). This index is a ranking of countries based on the diversity and complexity of their export baskets. The ECI is based on the concept that countries with diverse and complex export structures are likely to be more developed and innovative.[28] Data from the GII 2023. shows that African economies have the least diverse and complex export basket worldwide, with Angola having the least complex export basket in 2020 (-2.51) and Tunisia having the most complex in the same year (0.46).

The ECI could assist in the assessment of the African industrialisation process (its readiness), especially in the context of the Continental Free Trade Agreement.

High-tech imports and exports as a% of total trade. High-tech trade refers to the exchange of goods and services characterised by a high level of technological sophistication and innovation. These products are often associated with advanced scientific and technical knowledge, cutting-edge R&D and the use of state-of-the-art technologies in their production processes. Participation in high-tech trade provides insights into a nation's ability to create, adopt and export advanced technologies. In 2021, high-tech exports accounted for an average of 0.53% of total trade among African economies, the lowest share globally. Tunisia had the largest share at 4.46% in 2021, followed by Morocco (2.14%) and South Africa (2.07%).

The ASTII programme is suggested to serve as the vehicle to monitor these indicators to advise African policymakers on matters of African industrialisation in the context of Agenda 2063.

6.2.6 Recommendations

GII as an instrument for policy learning. While the GII is often used for benchmarking innovation capabilities between countries, *African governments are encouraged to pay special attention to the characteristics of their innovation ecosystems by focusing on the individual indicators and tracking the progress of these indicators over time.* This practice will help governments implement corrective measures and shape effective policies.

Member countries are encouraged to establish a national task force for the Global Innovation Index (GII), which should have at least one administrative authority. This task force is intended to operate in a cross-sectoral, inter-ministerial and multidisciplinary manner. Its primary objective is to oversee the GII indicators that serve as the foundation for key priority areas within national innovation systems. The final aim is to allocate resources more reliably and efficiently by identifying areas where innovation efforts may be excelling or lacking.

The task force should be led by a GII national expert, who should liaise with other focal points at the national level responsible for submitting data to international organisations, collating the data used in the computation of the GII. The Task Force should prioritise the missing and outdated indicators, highlight the roles and responsibilities of actors involved in data collating processes and set the way forward in improving GII data coverage and quality. Particular attention will be paid to the indicators that impact Africa's industrialisation, namely domestic industry diversification, high-tech manufacturing, production and export complexity and high-tech exports and imports.

6.2.7 Conclusion

The GII has been recognised by international and regional institutions such as the United Nations Economic and Social Council and the SADC as a critical "tool for action" to assess and compare the innovation performances of countries and thus consolidate evidence-based innovation policy making. The characterisation of the innovation ecosystems provided in the GII, through the individual indicators and their progress over time, shall serve as an opportunity to learn about what works and what does not for an innovation ecosystem. The GII provides a solid framework for measuring the innovation performance of African economies to support their industrialisation drive.

28 The values of the ECI can be both positive and negative. A positive ECI value indicates that a country's export basket is more complex and diversified than what would be expected. Countries with positive ECIs are often those exporting a variety of technologically sophisticated and diverse products. Conversely, countries with negative ECIs may have a more concentrated export structure, potentially focusing on a narrower set of less sophisticated products.

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6.3 INNOVATION PERFORMANCE IN AFRICA

This section presents the status of innovation performance in the business sector, mainly focusing on manufacturing and services firms from three African countries, Egypt, Mauritius and South Africa, the reference period 2017-2019 for Egypt and 2019-2021 for both Mauritius and South Africa. The three countries, with a total of 169.921 million inhabitants in 2021, represent 12.2% of Africa's population (World Bank, 2024[b]) and a total gross domestic product (GDP) of US$801-billion in 2015 prices in 2021, with South Africa and Egypt being in the top three major contributors to Africa's total GDP (World Bank, 2024a). While these three countries do not accurately represent a continent of 55 countries, key lessons can be drawn, given that they represented 29.5% of Africa's total GDP in 2021.

The assessment of innovation at the firm level gives a wide range of information that can be used to indirectly gauge key aspects of innovation systems. While the previous chapter focused on the national R&D system, this chapter provides complimentary information on innovation activities such as capital expenditure on machinery and equipment, R&D and software, as well as expenditure on the acquisition and use of knowledge, product design, personnel training, pilot scale production and market analysis from a firm level perspective. The survey specifically looks at firms that introduced new products and processes organisational and marketing innovations and other aspects such as challenges faced by firms and sources of useful information for innovations.

The section outlines the structure and content related to innovation measurement in the business sector of three African countries: Egypt (2017-2019) and Mauritius and South Africa (2019-2021).

1. The introductory subsection leads into definitions and an overview of innovation measurement
2. Guidelines for measuring and interpreting results, along with an overview of the sample, are provided
3. Key policy-relevant questions are addressed throughout, covering the extent of innovation among African firms, types of innovation and how firms innovate, including investment in R&D
4. The impacts of innovation activities on firms are investigated, focusing on the novelty of product innovations, outcomes and the use of intellectual property rights

5. Factors promoting innovation are examined, including employee qualifications, revenue and sources of information
6. The section concludes with an exploration of major factors that hinder innovation, comparing perspectives from firms with and without innovation activities

6.3.1 Definition of Innovation and Guidelines on Measurement

Innovation measurement places firms at the core of the innovation system, highlighting their role in establishing the technological and industrial foundations across all sectors of the economy, including communication, finance, agriculture, manufacturing, education and healthcare. While innovation occurs universally, it is context-dependent and holds different meanings for various actors: from a farmer breeding new crop and livestock varieties to a chef creating new recipes, a hospital developing innovative diagnostic or treatment procedures or an engineer refining aircraft landing gear. Given these diverse perspectives, a shared and comprehensive understanding of innovation is essential for countries, Firms and individuals to leverage its economic, Social and environmental potential fully.

According to the fourth edition of the Oslo Manual, business innovation is defined as "a new or improved product or business process (or a combination of both) that differs significantly from the firm's previous products or processes and has been introduced to the market or implemented by the firm" (OECD/Eurostat, 2018:33, Para 1.30). More broadly, innovation refers to a new or improved product or process (or combination thereof) that significantly differs from previous products or processes and is either introduced to potential users (in the case of a product) or implemented within an organisation (in the case of a process) (OECD/Eurostat. 2018:32. Para 25). The use of the term "unit" in this definition extends beyond firms. signifying that any institutional unit, including households and individuals, can be responsible for innovation.

In the fourth edition of the Oslo Manual, based on evidence from cognitive testing organisational and marketing innovations are no longer considered, simplifying the measurement of innovation (OECD/Eurostat, 2018:131, Para 1.32). For this report, however, the definition adopted derives from the third edition of the Oslo Manual (OECD. 2005), which defines innovation as "the implementation of a new or significantly improved product (good or service), process, marketing method or organisational method in business practices, workplace organisation or external relations" (OECD/Eurostat, 2005:146-150). The critical criterion for innovation is its implementation. A product is considered implemented when it is introduced to the market or utilised by the firm and new or significantly improved processes, marketing methods or organisational strategies are implemented when incorporated into the firm's operations (OECD/Eurostat, 2018:68-69).

Given the variety of terms used to describe innovation, it is crucial to recognise that innovation can impact business performance by either enhancing existing structures or improving internal operations – termed core innovations (Anthony et al. 2014) – or by generating new growth through reaching new customer segments or markets, often via new business models – termed new growth innovations (Harrison et al, 2014).

The innovation survey questionnaire used by the three countries was modelled on the EU Community Innovation Survey (CIS) series questionnaire. This instrument collects data on general firm information, including primary business activity, firm age, number of employees and total turnover. It then queries whether the firm introduced a new or significantly improved product or process to the market. Additional sections address ongoing or abandoned innovation activities, innovation-related expenditures, sources of information for innovation organisational and marketing innovation, intellectual property and barriers to innovation, among other topics.

6.3.2 Guidelines on Interpreting the Innovation Results

Given the substantial socio-economic disparities across the countries in the sample, as well as variations in firm size, sector, industry and market context, the interpretation of the results requires caution. While the teams involved in data collection may share a common understanding of the importance of high-quality data, practical realities – such as resource constraints, firm size, national priorities, institutional beliefs, legal frameworks and the comprehension of survey questions – inevitably influence the quality of data collected. Despite efforts to ensure comparable data quality and standards, drawing conclusions about the relative innovativeness of firms across countries is not feasible.

Moreover, measuring innovation is inherently costly and identifying the most effective tools for collecting innovation data poses challenges from a cost-benefit perspective. Even in cases where large firms have formalised innovation processes and practices, measuring the firm culture and business environment that drives innovation remains difficult. However, these factors are often critical in guiding decisions on the allocation of limited resources – such as human capital, finances, time and networks – toward innovation activities. These same elements also contribute to firms' persistence in nurturing promising but uncertain ideas and untested products. Such uncertainties are more manageable for firms with prior experience introducing innovations to the market. These firms have learned valuable lessons in navigating legal and regulatory barriers and can access both established and emerging networks. Additionally, they often mitigate risk by forming strategic partnerships, even with competitors, to ensure success.

Most of the countries involved in the AIO-4 report have limited experience with innovation surveys and do lack enough resource to sustain the production of innovation data. Egypt and South Africa are more experienced with four rounds of surveys, while Mauritius is on its first with dataset submitted to AUDA-NEPAD. As such, both the firms and national teams conducting the surveys have limited experience in completing and analysing innovation survey questionnaires and data. Under these circumstances, variations in survey instruments, sampling methodologies and population samples undermine the feasibility of international comparisons, benchmarking of innovation indicators and tracking of performance across countries over time (Anthony, Duncan and Pontus, 2014). Therefore, it is not possible to conclude that (a) one country is more innovative than another or (b) firms within the same economy are becoming innovative, given the lack of longitudinal data for over-time comparison.

Despite these limitations, significant insights can be drawn from the emerging data to guide policymakers, businesses and R&D leaders in developing appropriate strategies and responses. Importantly, several survey team members have participated in regional and national training sessions focused on the theoretical, analytical and practical aspects of real-world innovation surveys, methodologies and analysis, thereby ensuring a minimum level of confidence in the findings. Furthermore, the national data were reviewed at the regional level, where feedback allowed country teams to validate or revise their data before submission. A major challenge was the very low response rate from countries surveyed, with only three providing results. Countries have experienced technical challenges in the collection and analysis of data. In the future, it would be beneficial to enhance and support the capacity of additional country teams directly involved in conducting national surveys.

The results of the innovation surveys will, among other things, provide insights into the rate of innovation in countries that submitted complete datasets, the sources of relevant ideas and information for, innovation objectives, key drivers of innovation at the firm level, the impact of support measures on innovation activities, cooperation arrangements or strategic alliances for innovation and the primary barriers to innovation. Some of these factors may be more pronounced in one country than another due to differences in national innovation policy environments.

6.3.3 Snapshot Overview of the Sample and Innovation Surveys

The innovation survey results presented in this section pertain to the implementation of new or significantly improved goods, services, processes organisational or marketing methods by firms across various economic sectors. In Table 6.2, a total of 62 636 firms were surveyed from a target population of 431 217 businesses across three participating countries. South Africa contributed the largest sample size, with 57 025 firms surveyed. Egypt provided a sample of 3 800 firms, while Mauritius had the smallest sample with 1 811 firms, of which 1 101 were successfully realised. The survey captured all four types of innovation: product, process organisational and marketing innovation. Each of these forms plays a crucial role in successfully implementing a single innovation and supporting innovative business operations.

Table 6.2 Characteristics of innovation surveys

Reference period	2017-2019	2019-2021	2019-2021
Country	**Egypt**	**Mauritius**	**South Africa**
Edition of Oslo Manual (OM) used (OM 2005/OM 2018)	OM 2018	OM 2018	OM 2018
Targeted business sector population size	264,737	109,455	57,025
Stratified random sample used (Yes/No)	Yes	Yes	Yes
Original sample size	3,800	1,811	57,025
Realised sample size	3,800	1 101	57,025
Sample to population extrapolation techniques used (Yes/No)	Yes	No	No
Response rate (%)	100	61	33.2
Number of innovative firms in completed returns	1,101	747	29,158
Number of innovative firms in extrapolated population	77,356	74,262	35,258
Percentage of innovative firms in extrapolated population (%)	29.2	67.8	61.8

6.3.4 How Innovative are African Firms?

6.3.4.1 Are African Firms Innovative?

The innovation process varies across organisations, within organisations and according to product, sector and market segment. Firms and entrepreneurs continuously seek new ways to enhance allocative efficiency and drive productivity growth. Empirical literature, predominantly based on data from OECD countries, consistently demonstrates a positive relationship between firm-level innovation and productivity (EU, 2017; Statistics New Zealand, 2005), as well as innovation and employment, R&D and productivity and innovation and profitability. In Latin America, similar linkages between innovation and productivity have been documented (Crespi and Zuniga, 2012; Zuniga and Crespi, 2013; Crespi, Tacsir and Vargas, 2014), although evidence outside the region remains limited. A broader analysis, including data from Sub-Saharan Africa, South Asia, Eastern and Central Europe and the Middle East, further highlights the positive impact of innovation on productivity (Xavier and Silvia, 2016). Among the 62.636 firms surveyed across the three countries, 49.4% were identified as innovative (see Figure 6.3). The innovation rate, defined as the proportion of firms that have introduced a new or significantly improved product, process. organisational method. or marketing method, is expressed as a percentage of the total sample of firms (OECD/Eurostat, 2005: 47).

It is also important to note that innovation surveys adopt a “subject approach” by considering all innovation activities implemented by a firm, rather than an “object approach”, which would examine individual projects (OECD/Eurostat, 2005: 20-21). Innovation activities can be ongoing or abandoned, referring to initiatives that are either still in progress or terminated for various reasons. Firms with ongoing or abandoned innovation activities may still have product or process innovations during the reference period, as illustrated by the case of Ethiopia (see Figure 6.3, Tables 6.2 and 6.3). To remain competitive, it is advantageous for firms to develop an innovation strategy, regardless of the number of successful innovation activities completed.

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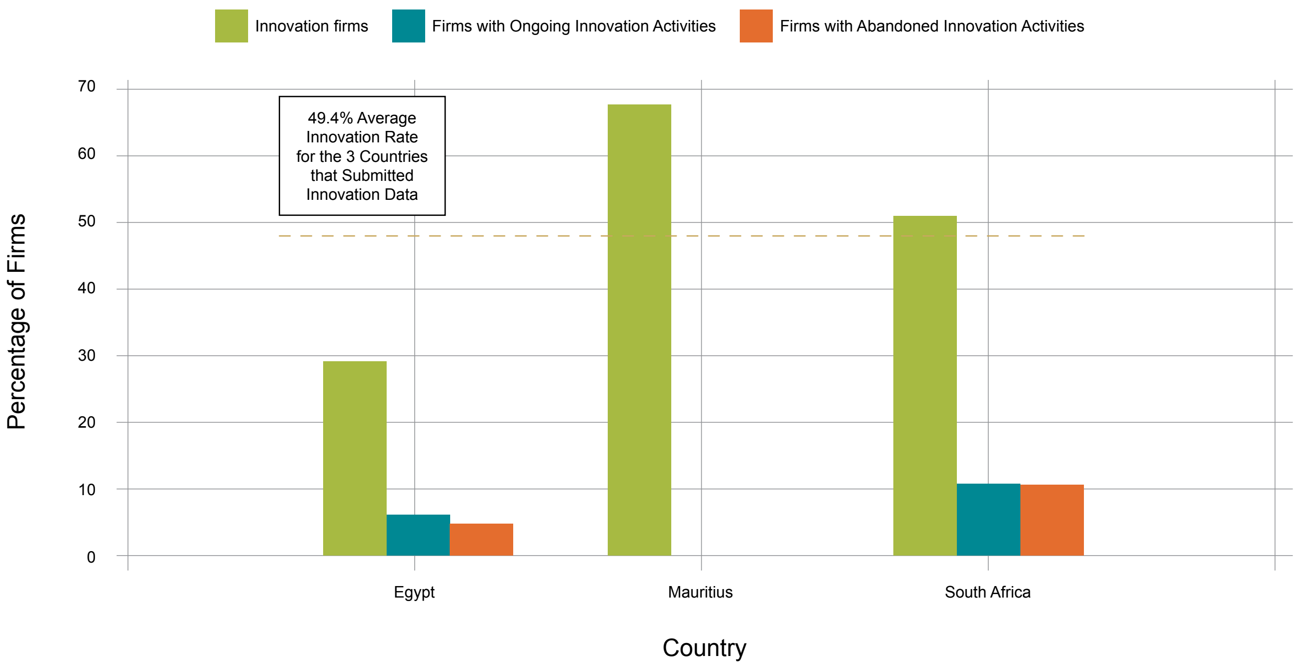
Figure 6.3 Innovation rates (chart with innovative firms, firms with ongoing innovation activities and firms with abandoned innovation activities, by country)



The average innovation rate varies widely at the national level (see Figure 6.3 and Table 6.3 and Table 6.4 for details). As shown in Figure 6.3, the innovation rates for all the countries range from a low level of 29.2% for Egypt, South Africa with 51.1%, and Mauritius with a calculated innovation rate of 67.8%.

In South Africa, firms reported a 10.6% rate for abandoned innovation activities and in Egypt, the rate was 4.7%. Although the overall innovation rates are higher, the wide variations are not unique to African countries. The OECD (OECD, 2009) and the EU have observed similar wide variations among their countries. For instance, about 49% of the firms in EU-2018 were innovative but varied from 67% for Germany down to 12.8% for Romania.

Table 6.3 shows details on firms with ongoing and abandoned innovation activities as a percentage of all firms for the three countries, Egypt, Mauritius and South Africa, though only South Africa provided the full details of the breakdown of firms with ongoing and abandoned innovation activities. Egypt had more firms with ongoing than abandoned innovation activities, 6.1% and 4.8%, respectively. South Africa showed a similar pattern, though it had higher proportions of firms that fell into these categories, 35.6% and 12.2%, respectively. However, South Africa had no firms with only ongoing innovation activities. Similarly, South Africa had no firms with only abandoned innovation activities but had 12.7% of firms with only ongoing and/or abandoned innovation activities. With relatively lower proportions falling into the ongoing and/or abandoned innovation categories, this indicates that firms' innovation efforts were largely a success. This is further supported by the lower levels of abandonment of innovation activities compared to ongoing innovation activities.

Table 6.3 Innovation rate, ongoing and abandoned innovation activities

Targeted business sector population size	Egypt		Mauritius		South Africa	
	n	%	n	%	n	%
	264 737	100.0	1 101	100.0	57 025	100.0
Innovative firms	77 356	29.2	747	67.8	29 158	51.1
Firms with abandoned innovation activities	16 127	6.1			20 299	35.6
Firms with abandoned innovation activities	12 691	4.8			6 929	12.2
Firms with ONLY ongoing innovation activities					0	0.0
Firms with ONLY abandoned innovation activities					0	0.0
Firms with ONLY ongoing and/or abandoned innovation activities	34 023	12.9			6 100	10.7

Table 6.4 presents the innovation rate by product and process innovation for Egypt. As shown in Figure 6.3. 29.2% of the target population of Egyptian firms were innovative. Among these innovative firms, more implemented process innovations (28.7%) than product innovations (22.0%), which also translates to more firms that implemented only process innovations (28.3%) than product-only innovators (16.4%). Firms need to apply different process innovations at various stages of the product value chain, from production to marketing.

Table 6.4 Disaggregated data on innovation rate by product and process innovations for Egypt

Innovation rates: product and process innovations	N (estimate)	(%) with respect to targeted business sector size
All Firms	264 737	100.0
Firms with product innovations	58 217	22.0
Firms with process innovations	75 958	28.7
Firms with ONLY product innovations	43 529	16.4
Firms with ONLY process innovations	75 042	28.3
Firms with BOTH product and process innovations	41 886	15.8
Non-innovative firms	187 381	70.8

At the national level, South African firms' propensity to implement product innovations or only product innovations (36.9%) was the same as their propensity to implement process innovations or only process innovations (Table 6.5). At the sector level, however, firms' propensity to implement product or only product innovations was either higher or lower than their propensity to implement process or only process innovations, depending on the need and ability to implement each of these types of innovation.

Table 6.5 Disaggregated data on innovation rate by product and process innovations for South Africa

Innovation rates, ongoing and abandoned innovation activities	N (estimate)	(%) with respect to targeted business sector size
All Firms	57 025	100.0
Firms with product innovations	21 062	36.9
Firms with process innovations	21 062	36.9
Firms with ONLY product innovations	8 096	14.2
Firms with ONLY process innovations	8 096	14.2
Firms with BOTH product and process innovations	12 966	22.7
Non-Innovative Firms	27 867	48.9

The South African Business Innovation Survey 2019-2021 classified innovations according to the latest edition of the Oslo Manual published in 2018, which recommends classifying innovations into product and business process innovations, with the latter including organisational and marketing innovations. Hence, organisational and marketing innovations were included in the process innovations.

6.3.4.2 Innovation Rates by Firm Size and Industry Sector

a) Innovation Rates by Firm Size: Egypt, Mauritius and South Africa

This section examines the impact of firm size on innovation rates in Egypt, Mauritius and South Africa as shown in Table 6.6. Firm size often reflects the extent of available resources, global competitiveness, relationships with public institutions and organisational agility or resilience. Generally, larger firms within specific industry sectors are more likely to possess highly skilled labour, extensive production networks and substantial financial and technical resources. While smaller firms may exhibit greater agility, they typically face constraints in internal resources. Internally, large firms manage more complex product portfolios and professional structures, often necessitating significant resources for R&D and innovation activities. Externally, larger firms hold substantial market power, influencing the diffusion of innovations. Large and small firms' approaches differ notably in terms of R&D productivity, investment levels and innovation management. Large firms are traditionally seen as primary contributors to technological advancement, while smaller firms are regarded as catalysts of change, fostering technological diversity that enhances productivity and stimulates innovation.

Table 6.6 Innovation rates for Egypt, Mauritius and RSA by main firm size groups and sub-groups

Country	Number of firms (N)	Innovative firms		Firms with ongoing and/ or abandoned innovation activities	
Firm Size*		**Number**	**%**	**Number**	**%**
EGYPT	**264 737**	**76 830**	**29.02**	**64 569**	**24.39**
Micro (<10)	93 059	12 787	13.74		
Small (10-49)	56 870	6 615	11.63	6 912	12.2
Medium (50-249)	34 611	13 152	38.00	13 319	38.5
Large (≥ 250)	80 197	44 276	55.21	44 338	55.3
MAURITIUS	**109 455**	**1 373**	**1.3**		
Small (10-49)	105 919	1 146	1.1		
Medium (50-249)	2 709	160	5.9		
Large (≥ 250)	827	67	8.1		

Size classes in the South African Business Innovation Survey 2019-2021were based on turnover instead of employment. Hence, data from these size classes is excluded from this table, as it would be incomparable with employment-based size classes recommended by the Oslo Manual.

This fourth Edition of the Outlook relies on innovation survey data from three countries: Egypt, Mauritius and South Africa. However, South Africa could not provide data by firm size as their survey did not include this categorisation. In Mauritius, small firms (10-49 employees) dominate the business, with more than 95% of the total number of firms. In contrast, the Egyptian sample is dominated by micro firms with 35% and large firms with 30% of the total number of firms.

• Innovation Rate by Firm Size for Egypt

Table 5.3.5 presents innovation rates in Egypt segmented by firm size, with responses from 264737 firms. Of these, 29.02% engaged in innovative activities, while 12.9% reported ongoing or abandoned innovation efforts (refer to Table 6.7). The firm size distribution was as follows: 35% micro, 22% small, 13% medium and 30% large. Large firms demonstrated the highest innovation rate at approximately 16.7%, followed by firms at medium-size 5%, micro size 4.8% and small firms at 2.5%. Consistent with patterns observed in countries where increases in firm size correlated with higher shares of ongoing and abandoned innovation activities. Specifically, only 12.2% of small firms and 38.5% of medium-sized firms reported abandoned innovations, whereas 55.3% of large firms indicated the same. Large firms recorded the highest ratio of successful innovations to ongoing and abandoned activities (67% to 22%), followed by medium-sized firms (72% to 10%) and small firms (50% to 4%). This trend suggests that small firms may have more efficient innovation processes or may strategically focus on low-risk, rapid-to-market innovations.

• Innovation Rate by Firm Size for Mauritius

Mauritius reported a low innovation rate of 1.3%. Of the 109,455 firms surveyed, 2 367 introduced a new or significantly improved product to the market or implemented a novel business or marketing model.

These figures were further analysed by firm size: small (10-49 employees), medium (50-249 employees) and large (≥ 250 employees). The sample comprised 105 919 small firms, 2 709 medium firms and 827 large firms, representing 96.8%, 2.4% and 0.76% of the total sample, respectively. Innovation rates increased with firm size, with 1.1% for small firms, 5.9% for medium firms and 8.1% for large firms.

b) Innovation Rates by Industry Sector: Egypt, Mauritius and South Africa

• Innovation Rate by Industry Sector for Egypt

As seen in Table 6.7, the overall innovation rate (in terms of the number of innovative firms as a percentage of all firms) for Egypt was 29.2% (see also Figure 6.3). Disaggregated by industry sector, the manufacturing sector recorded a higher innovation rate (72.6%) than the mining sector (9.9%). This may be attributed to the fact that Egypt’s Economy is driven by multiple sectors (manufacturing, agriculture, petroleum exports and services). excluding mining (CIA, 2023).

Table 6.7 Innovation rate for firms in the mining, agriculture, manufacturing and construction sectors for Egypt, Mauritius and South Africa

Country	Number of firms (N)	innovative firms		Firms with ongoing and/ or abandoned innovation activities	
	Number	Number	%	Number	%
EGYPT *					
All firms	**264 737**	**77 356**	**29.2**	**34 023**	**12.9**
Mining	131	13	9.9		
Manufacturing	61 358	19 126	72.6		
Construction					
Services					
MAURITIUS					
All firms	**1 101**	**747**	**67.8**		
Mining	33	18	55		
Manufacturing	99	73	74		
Construction	969	656	68		
Services					
SOUTH AFRICA					
All firms	**57 025**	**29 158**	**51.1**	**21 892**	**38.4**
Mining	1 550	829	53.5	76	4.9
Manufacturing	18 978	9 470	49.9	2 334	12.3
Construction	490	252	51.4	21	4.3
Services	36 007	18 607	51.7	3 670	10.2

* Egypt and Mauritius supplied did not supply industry sector level data on firms with ongoing and/or abandoned innovation activities

• Innovation Rate by Industry Sector for Mauritius

Mauritius reported an overall innovation rate of 67.8% (Table 6.7 and Figure 6.3). The manufacturing sector had the highest innovation rate (86.9%). followed by construction (85.0%) and services (75.1%). This matched with the country's GDP distribution by sector in 2022, with services and manufacturing among the top contributors (CIA, 2022).

• Innovation Rate by Industry Sector for South Africa

The overall innovation rate for South African firms during the period 2019-2021 was 51.1% (Table 5.3.5 and Figure 5.3.1). By sector, mining, manufacturing, construction and services reported innovation rates that were similar to this national innovation rate, with mining at the top of the list (53.5%), followed by services (51.7%), construction (51.4%) and manufacturing (49.9%). This is consistent with the GDP statistics of 2022 and 2023, which show that the services sector contributed 62.6% to GDP and the industry (including mining and manufacturing) contributed about 25.0% to GDP in 2023 (Stats SA, 2022; 2023). The South African construction sector had the least proportion of firms with innovation activities that were still ongoing and/or abandoned innovation activities (4.3%), followed by the mining sector (4.9%) and one with the highest proportion of firms was the manufacturing sector (12.3%). As seen above (based on the proportion of innovative firms), this further confirms that innovation performance in the mining sector was higher than in the manufacturing sector, indicating that firms in the former sector used more efficient and effective strategies to implement innovation.

6.3.4.3 Innovation Pipeline for Firms (Firms with Ongoing and/or Ongoing Innovation Activities)

Firms are increasingly obligated to innovate to maintain competitiveness. Consequently, firms whose project pipelines are defined by a series of profitable initiatives and insights from discontinued projects should adopt a proactive, forward-looking approach to innovation. Such an innovation portfolio should include both ongoing and discontinued initiatives, positioning firms to adapt to the dynamic business landscape – including strategy shifts, cost fluctuations, regulatory challenges and competition.

The survey findings indicate that, overall, most firms reported more ongoing than abandoned innovation activities. Nationally, Egypt showed a higher incidence of over-abandoned innovations, while South African firms had nearly equal numbers in each category (see Figure 6.3). The innovation pipeline data reflects both innovative and non-innovative firms. As innovation rates are not analysed by firm size and industry sector across all three countries, a detailed discussion by country is not presented here. However, the data disaggregated by firm size and industry sector for Egypt and Mauritius is discussed in Section 6.3.4.2.

In sectors with stringent regulatory requirements, such as manufacturing and services, market-ready innovations may face delays in deployment. Table 6.2 shows that 10.6% of firms in South Africa and approximately 6.7% of firms in Egypt encountered challenges in achieving effective innovation outcomes. Abandoned innovation activities may misalign with current business strategies, be too radical or entail prohibitively high costs. Nevertheless, such innovations may later prove valuable in niche markets or be sold to other firms. Ultimately, identifying the optimal context for applying and managing innovations is critical for business sustainability (Burnett, 2011).

6.3.5 What are the Different Types of Innovation?

Africa has articulated a vision to emerge as a global centre for manufacturing and value addition, aligning with its commitment to achieving the objectives of Agenda 2063. The innovation survey results are presented as the rate of different types of innovation undertaken by firms across three countries. To enhance clarity, we also provide innovation rates disaggregated by type and firm size for countries that submitted complete datasets. On average, more firms engaged in product and process innovations than organisational and marketing innovations. Notably, among the surveyed firms, Mauritius reported a higher incidence of marketing and organisational innovations, South Africa led in process innovations and Egypt recorded the highest levels of product innovation activities.

Table 6.8 Number of surveyed firms with and without innovation activity

All firms	Egypt		Mauritius		South Africa	
	Number	%	Number	%	Number	%
	264 737	100.0	109 455	100	57 025	100.0
Innovation Active Firms: - Innovative Firms (Innovators) and/or - Firms with Ongoing and/or Abandoned Innovation Activities	77 356	29.2	84 204	76.9	35 258	61.8
Non-innovation-active Firms	18 7381	70.8	25 251	23.1	21 766	38.2

Table 6.9 Types of Innovations reported by Egypt, Mauritius and South Africa

Types of innovations	Egypt		Mauritius		South Africa	
	Number	%	Number	%	Number	%
Product Innovators (introduced New Goods and/or Services)	43 529	16.4	721	65.9	8162	14.3
Process Innovators	75 042	28.3	428	39.1	21 062	36.9
Entirely new or improved production of goods or services	54 652	20.6	439	40.1	21 062	36.9
Marketing Innovators	37 996	19.3	982	89.7		
Entirely new or improved distribution and logistics	30 210	11.4	272	24.9		
Entirely new or improved marketing and sales	44 080	16.7	982	89.7		
Organisational Innovators	37 996	14.4	903	82.5		
Entirely new or improved information and communication systems	29 716	11.2	353	32.3		
Entirely new or improved administration and management	36 081	13.6	291	26.6		

The South African Business Innovation Survey 2019-2021 classified innovations according to the latest edition of the Oslo Manual, published in 2018, which recommends classifying innovations into product and business process innovations, with the latter including organisational and marketing innovations. Hence, organisational and marketing innovations were included in the process innovations.

6.3.5.1 Product and Process Innovations

A closer look at product (goods and services) and process innovations suggests that process innovations were higher. However, wider differences were observed among countries (Table 6.8). For instance, South African firms reported that only 36.9% of process innovations and 51.7% of them are in the services sector. On the other hand, Egypt reported much higher innovation rates in the services sector at 75.1% with only 16.4% of product innovation.

6.3.5.2 Organisational Innovation

In today's competitive business landscape. firms ensure their survival by strategically transforming their operations at opportune moments. Like other institutions, firms continuously pursue new or enhanced methods for conducting business activities – spanning internal practices, external interactions and relationships – to strengthen their competitiveness. Innovation within a firm is largely driven by the behaviour and engagement of employees and employers alike. These new or improved business methods facilitate knowledge development and continuous learning, which, in turn, bolster the firm's competitive advantage. Such impacts may include streamlined workflows, novel management and implementation methods, enhanced transparency, improved customer service and new product or service offerings, among others.

The results suggest that a significant portion of organisational innovations focused on enhancing workplace roles, such as implementing new methods that allow employees to assume new responsibilities and control functions, followed by advancements in business practices. Organisational innovations thus play a crucial role in fostering workplace improvements, which are essential for business performance and operational sustainability. Consequently organisational innovations encourage employees and employers to adopt fresh perspectives, learn continuously and adapt proactively, irrespective of the challenges or opportunities they encounter. As illustrated in Table 6.8. Mauritius reported a higher proportion of firms implementing administration and management innovations (26.6%) than Egypt (13.6%).

6.3.4.3 Marketing Innovation

Marketing innovations aim to develop more effective solutions for addressing customer needs, fulfilling market demands and driving profitability. Marketing plays a pivotal role in ensuring the adoption of new commercialisation methods. whether to meet customer requirements or to create new market opportunities. Depending on the industry, these innovations may encompass new and significantly enhanced approaches to packaging, presentation, promotion, pricing and customer outreach. The use of self-service tools, such as social media, enables the creation of engaging and original marketing campaigns, often reducing both technical skill requirements and costs.

This section examines the extent of firm investments in developing new or improved marketing approaches. Focusing on innovations in design, product placement and pricing methods. The findings reveal that firms in the surveyed countries prioritise varied marketing strategies. This likely reflects the diverse nature of businesses and sectors across these countries. Generally, new methods for product placement were less common than innovations in design and pricing. At the national level, Mauritius reported the highest proportion of firms employing new marketing techniques and media (89.7%), while Egypt reported 19% (see Table 6.9).

6.3.6 How Do Firms Innovate?

6.3.6.1 How Do Firms Implement and Invest in Innovation?

To bring new ideas and concepts to market, firms often need to invest across multiple domains. One of the primary innovation-supporting activities is research and development (R&D), which aims to generate new knowledge and insights to competitively launch innovations. Successfully introducing new products and processes may also require investments in equipment and facilities, workforce training, marketing campaigns, staffing and licensing intellectual property from external sources. In the countries surveyed, most firms reported expenditures on acquiring equipment and machinery to facilitate innovation (see Table 6.9). South Africa was the only country where nearly 35% of firms engaged in R&D activities specifically to support innovation.

A deeper understanding of firms' resource allocation in market-ready innovation could benefit investors, policymakers and decision-makers. Generally, equipment acquisition was the most frequently cited expense related to innovation, followed by R&D spending and the acquisition of external knowledge. Governments aiming to promote innovation may consider supporting firms in acquiring capital goods and knowledge assets by funding R&D or offering incentives such as R&D tax rebates. In the case of Mauritius, apart from other innovation activities on which firms spent over half of the total national expenditure on innovation, the highest expenditure was on market introduction of innovations (17.8%), indicating that firms were trying new or improved strategies for establishing new or expanding their markets. The third highest expenditure was on the acquisition of equipment and machinery (13.0%), followed by acquisition of other external knowledge (9.4%), implying that firms were using equipment, machinery and other external knowledge (apart from extra-mural R&D) to implement their innovations. Smaller proportions of the total innovation expenditure went to training (2.6%) and design (1.2%), which implies that firms needed to train their staff on the equipment and machinery and used R&D and other external knowledge for product design, respectively.

Table 6.10 Expenditures on innovation activities for Mauritius and South Africa (%)

Type of innovation activities	Mauritius	South Africa§
Intra-mural R&D		26.3
Extra-mural R&D		9.2
Acquisition of equipment and machinery	13.0	
Acquisition of software		
Acquisition of another external knowledge	9.4	
Training	2.6	
Market introduction of innovations	17.8	
Design	1.2	
Other activities	55.9	
Total	**100.0**	

§ The South African Business Innovation Survey 2019-2021 collected data on expenditure on intra-mural and extra-mural R&D as well as activities intended for innovation activities (not categorised as the activities in this table) and non-innovation activities.

6.3.6.2 To What Extent Do Innovative Firms Engage in R&D Activity?

In this section, we present the results on the share of innovative firms that were engaged in R&D activities to support innovation. Among the three countries that submitted data on innovation, only South Africa reported on the R&D activities (Table 6.10). Whereas R&D activities are significant to support innovation, the table shows that 78% of firms innovated without R&D activities.

Table 6.11 Proportions of innovative firms that engaged in R&D activity (%)

Countries	Intra-mural (in-house) R&D		Innovative firms WITH R&D activities		Innovative firms WITHOUT R&D activities	
	Number	%	Number	%	Number	%
Mauritius*	37	5.0				
South Africa*	6 053	17.2	7 555	21.4	27 703	78.6

* Egypt did not supply data on R&D activities

6.3.7 What are the Impacts of Innovation Activities on fFrms?

6.3.7.1 How Novel are the Product Innovations by Firms?

The new *Oslo Manual* **(OECD, 2018) defines novelty as follows:**

"The novelty of an idea, model, method or prototype is linked to its potential uses, as determined by the characteristics of a product or process compared to alternatives and by the previous experiences of its provider and intended users" (OECD/Eurostat, 2018:46, Para 17).

The more novel a type of innovation is, the more it will run counter to systems and processes designed to strengthen and support the current business performance (Table 6.11). Firms need to have processes in place that link various innovation to their short and long-term goals. Therefore, some key questions that need to be addressed include: What is the novelty or uniqueness of the innovations reported by firms? How does the size of the firm and the type of industry influence the distribution of these innovations? Determining the novelty of an innovation is challenging, especially when comparing it among different firms. For the purposes of this report, novelty is defined as whether the innovation is new to the firm itself or new to the market. The global newness of the innovation is not considered in this report. The results related to the novelty of product innovations can be found in parts of Table 6.11.

Table 6.12 Innovation novelty assessment of firms that introduced new goods/services (number and % of firms)

Country	New to the firm		New to the market		Unchanged or only marginally modified	Total firms that introduced new goods or services
	Number	%	Number	%	Number	%
South Africa*§		33.3		26.2		21.7

* Egypt and Mauritius did not supply data on novelty of their firms' innovations

§ Percentages are based on percentage breakdown of turnover by sales of products new to the firm, new to the market and unchanged or marginally modified

6.3.8 What are the Outcomes of Innovation?

As part of understanding the impacts of innovation, it is important to examine its highly important outcomes. Among the three African countries whose innovation performance is presented in this chapter (Egypt, Mauritius and South Africa), only South Africa supplied data on outcomes from its firms' innovating. Table 6.12 shows that South African firms experienced a range of outcomes emanating from their product and business process innovations. Overall, businesses reported that innovation had positive impacts on their competitiveness. Among the outcomes of interest in this presentation (Table 6.12), improved quality of goods was the most highly rated outcome (42.2%), followed by increased range of goods (31.3%) and new markets entered (29.3%). New markets entered were the least highly rated outcome (12.4%). This implies that firms' innovations mostly focused on and succeeded in improving the quality and range of goods rather than accessing markets for their goods and services.

Table 6.13 Effects of product innovation implemented by Innovative firms [number (%)]

Country	Increased range of goods	Entered new market*	Increased market share	Improved quality goods or services†
South Africa*	11 225 (31.3%)	10 049 (29.3%)	4 370 (12.4%)	14 955 (42.4%)

* Egypt and Mauritius did not supply data on their firms' outcomes of innovation

6.3.9 To What Extent are Firms Using Intellectual Property Rights in Their Business?

With the advent of growing global interconnectedness and digitalising economies, it is important to understand how firms use intellectual property rights (IPR) to implement their innovations. In this report, the relevant data for the three countries that submitted innovation data (Egypt, Mauritius and South Africa) are presented in Table 6.13. Egypt and Mauritius did not submit data for all methods of intellectual property rights (IPR), while South Africa did. Egypt had a low proportion of innovative firms that registered an industrial design (2.2%) and applied for a patent outside the country (1.7%). In comparison, Mauritius had slightly higher proportions of firms using various IPR methods. In Mauritius, the highest proportion of firms registered a trademark (8.3%), followed by those that secured a patent in their own country (7.1%) and registered an industrial design (2.7%). The proportion of firms in South Africa that utilised some form of intellectual property rights (IPR) was generally higher than in Egypt and Mauritius, highlighting South Africa's greater level of industrialisation. Among the IPR methods employed by firms, the top three were: registering a trademark (18.0%), securing a patent in their own country (17.3%) and claiming copyrights (12.6%). Notably, more firms applied for patents domestically (17.3%) than sought patents internationally (7.5%), which suggests that South Africa has significant potential to further develop its own IPR system.

Table 6.14 Innovative firms that used intellectual property rights [number (%)]

Firms with intellectual properties							
Country	**Innovative firms**	**Secured patent in own country**	**Applied for patent outside of own country**	**Registered an industrial design**	**Registered a trademark**	**Claimed copyrights**	**Granted a licence on any IP resulting from Innovation***
Egypt*	77 356		1 319 (1.7%)	11 706 (2.2%)			
Mauritius*	747	53 (7.1%)		20 (2.7%)	62 (8.3%)		
South Africa	29 158	5 030 (17.3%)	2 189 (7.5%)	2 071 (7.1%)	5 258 (18.0%)	3 668 (12.6%)	2 950 (10.1%)

* Egypt and Mauritius did not supply data on use of some intellectual property rights

6.3.10 What Factors Promote Innovation?

6.3.10.1 Are the Qualifications of Employees and Revenue Favourable for Firms to Engage in Innovation Activities?

A firm's knowledge base is highly correlated with its workforce education, skills and experience. The workforce participates in the sourcing and implementation of new ideas whose origins may be internal or external to the firm. Therefore, a firm relies on its workforce as the major asset that is critical to the firm's development and implementation of its product and process innovations (AUDA-NEPAD, 2019). Among the three African countries which submitted innovation data for this fourth edition of the African Innovation Outlook (Egypt, Mauritius and South Africa), only South Africa supplied data on the composition of the workforce by headcount and qualifications for innovating and non-innovating firms (Tables 6.14, 6.15 and 6.16).

The results in Table 6.14 show that, on average, the ratio of employees with a diploma or degree per firm was slightly higher for firms without innovation activity (0.35) than for firms with innovation activity (0.33). Similarly, Table 6.15 shows that, on average, firms without innovation activity had a slightly higher ratio of employees with a diploma or degree per total employees (0.26) than firms with innovation activity (0.25). Consistently, the results in Table 6.16 show that the proportion of non-innovative firms was marginally higher (26.5%) than the corresponding proportion of innovative firms (24.2%). This suggests that firms lacking innovation may start innovating through their workforce's participation. Further, the results in Table 6.16 also show that the proportion of turnover for innovative firms (as a percentage of total turnover) was notably higher (67.5%) than for non-innovative firms (32.5%). This indicates that, on average, innovative firms generate higher turnover than non-innovative firms.

Table 6.15 Ratio of employees with diploma or degree per firm and per total employees

South Africa	Ratio of employees with diploma or degree per firm*	Employees with diploma or degree per total employees**
With innovation activity	0.33	0.25
Without innovation activity	0.35	0.26

* Egypt and Mauritius did not supply data on employees with a diploma or degree per firm
** Egypt and Mauritius did not supply data on employees with a diploma or degree per total employees

Table 6.16 Percentage distribution of firms' turnover and staff qualifications

Country	Turnover for innovative firms as % total turnover	Turnover for non-innovative firms as % total turnover	Innovative firms: number staff with degree or diploma		Non-innovative firms: staff with degree or diploma	
			Number	%	Number	%
South Africa*	67.5	32.5	1 059 846	24.2	664 264	26.5

* Egypt and Mauritius did not supply data on staff turnover and staff qualifications by innovative and non-innovative firms

6.3.10.2 What Sources of Information Do Firms Draw on to Innovate?

To get to a point where firms innovate (innovative firms) – beyond just having innovation activities – firms rely on information from a wide range of sources (CeSTII, 2020). For this AIO-2024 report, only South Africa submitted results on sources of information for innovation, which is presented in Table 6.17. The results show that 39.6% of innovative businesses rated internal sources within their own firm or group as highly important to innovation. Where businesses did turn to external sources of information, it was most likely to be those directly involved in their value chains, primarily clients or customers (58.1%) and suppliers of equipment, materials and software (44.6%), competitors (26.1%), professional and industry associations (16.1%), universities or higher education institutions (13.6%) as well as consultants (13.5%). Government or public research institutions (8.4%), scientific journals (7.9%) and conferences, trade fairs and exhibitions (7.6%) were not highly rated as sources of information for innovation.

Table 6.17 Sources of information for innovation by innovative firms (number and %)

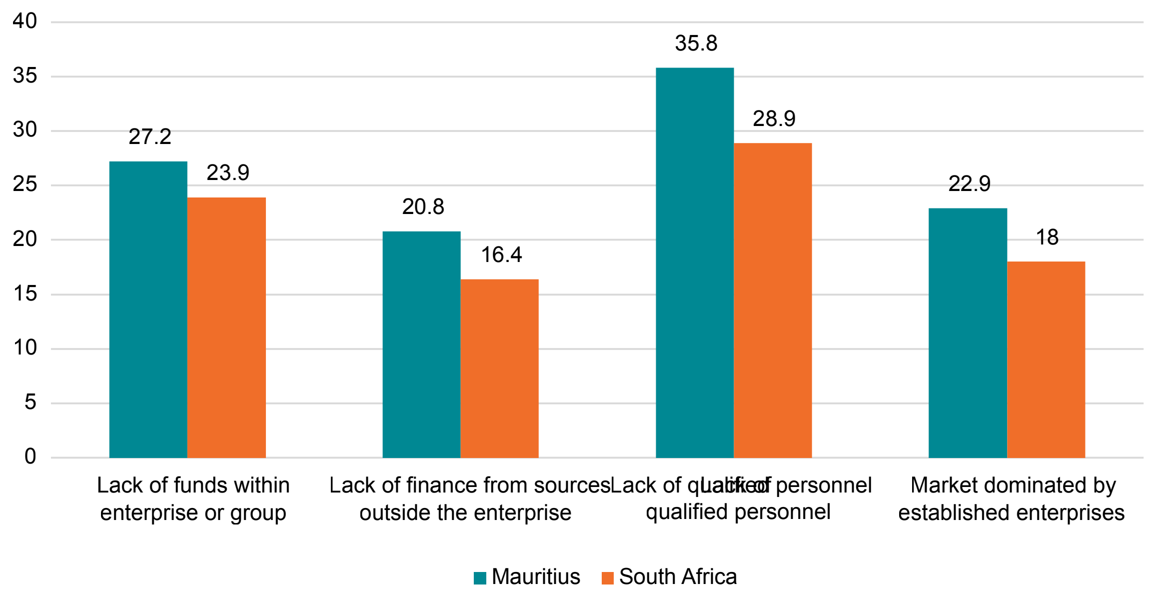
Information source	South Africa*	
	Number	%
All innovative firms	29 158	100.0
Sources within firm or group	11 547	39.6
Suppliers of equipment. materials and software	13 006	44.6
Clients or customers	16 943	58.1
Competitors	7 608	26.1
Consultants	3 929	13.5
Universities or Techn	3 961	13.6
Government or public research institutions	2 450	8.4
Conferences. trade fairs and exhibitions	2 224	7.6
Scientific journals	2 303	7.9
Professional and industry associations	4 708	16.1

* Egypt and Mauritius did not supply data on sources of information for innovation

6.3.10.3 What are the Major Factors that Hamper Innovation?

A firm may choose not to innovate due to barriers it faces, which can extend its competitiveness. Therefore, it is important to understand firms' perceptions of barriers to innovation as essential evidence to promote and support innovation in the future (CeSTII, 2020). Figure 6.4 presents the proportions of firms in Mauritius and South Africa[1] that rated selected barriers to innovation as highly important. The results in Figure 6.4 generally have low proportion of firms that identified any of the selected barriers to innovation as 'highly important'. However, factors related to knowledge or skills of personnel and internal innovation funding were identified as the most 'highly important' barriers to achieving greater innovation activity for their firms. Factors related to external innovation funding were the least rated as “highly important” barriers to innovation, followed by factors related to market competition. Egypt did not supply data on barriers to innovation.

Figure 6.4 Proportion of firms (out of total business sector target population) that rated selected barriers to innovation as highly important for Mauritius and South Africa



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6.4 INNOVATION IN THE GOVERNMENT* SECTOR

* Government refers to established political processes with legislative, judicial or executive authority and occurs at the national, regional and local administrative levels, excluding public corporations (OSLO, 2018).

6.4.1 Background

The literature has mainly quantified and discussed the significance of innovation in the private sector. However, owing to the unique nature of the institutional structure, government sector innovation requires different definitions and attention. Oslo (2018) defines innovation as *"…a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)…"* Thus, adapting the Oslo definition and considering the government as a unit, innovation in the government sector is the development, implementation and use of new strategies and means that enable government entities to enhance government sector efficiency, essential service delivery and responsiveness to the needs of their citizens (OECD, 2019). In essence, innovation in the government sector refers to significant improvements to public administration and/or services. This implies that innovation in the government sector goes beyond science-based and technological enhancements to include implementations of new or significantly improved operations or productions and new or improved methods of collaborating with partners.

> Innovation in the government sector is the creation of new and/or improved strategies that enable government units enhance administration, efficiency, government service delivery and responsiveness to the needs of the citizens.

Public servants operate in highly dynamic and complex work environments characterised by ever-changing citizen expectations, shrinking public resources and rapid technological changes, which require them to be innovative and creative when dealing with complex policy problems. Thus, innovation needs to be at the heart of the government sector's efforts to improve performance and develop new capabilities, new models and new approaches in the delivery of public services. For example, governments worldwide use digital technologies to innovatively transform operations, share information, make decisions, deliver services and engage in participatory policymaking (UN, 2020). Innovation in the government sector provides opportunities to support the achievement of the 2063 Agenda and the Sustainable Development Goals (SDGs) by enhancing the efficiency and effectiveness of public service delivery and reaching those left behind (UN, 2020).

In recent decades, many African governments have made strides to improve the innovation of the government sector. These policy strategies range from developing whole-of-government innovation strategies that address the role of the government sector as an innovator (e.g. Rwanda) to creating structures to support individual organisations in their innovation processes (e.g. South Africa). An in-depth analysis of government innovation from countries that rank highest on the UN E-government development index (EGDI). EGDI is a composite measure of three sub-measures (online service index, human capital index and telecommunication infrastructure index) that the United Nations uses to rank its Member States' government innovation. Conceptually, the measurement of innovation in government and, by extension, the public sector is difficult because of the absence of markets for government goods. Oslo (2018) posits that the absence of markets changes the incentives for innovation and the reliance on price-based measures. Thus, measurements of innovations in government should rely on subjective or self-reported measures. The United Nations eGovernment Development Index focuses on the collection of data biannually through a survey for three indicators. These indicators provide a basis for the estimation of an index to measure e-government readiness and performance in Member States.

The highest-ranking country from each REC and those countries that made a significant leap in the 2022 EGDI were considered. Some innovative approaches implemented by African governments include:

6.4.2 Digital Technologies and e-Government Services

Digital technologies and implementations of e-government services enable governments to meet new demands for online services, tailor services to individual needs through service personalisation. and reduce transaction costs, while innovation is still growing in Africa, some governments have been experimenting with innovative and creative ways to deliver public services, engage citizens and address complex policy problems.

In Kenya, the Huduma centers, established in 2013, strive to revolutionise public service provision, granting citizens access to diverse public services and information. These centres, known as "Huduma" in Kiswahili, operate as One-Stop-Shop hubs tailored to citizens' needs, leveraging integrated technology platforms. This holistic "One Stop Shop" model streamlines access to multiple public services and information from a unified location, cutting through the usual bureaucratic hurdles associated with governmental institutions. This initiative marks a significant departure from centralised governance to decentralisation. aiming to bring services closer to the Kenyan populace. The Huduma programme underscores the values of accountability, transparency and fostering trust in public service delivery. Notably, in 2015, Huduma Kenya received both the United Nations Public Service Award (UNPSA) and the AAPAM award, recognising its outstanding contributions to serving Kenyans and enhancing public service delivery. These accolades highlight Huduma's role as a beacon of transformational leadership in public service delivery (Government of Kenya, 2022).

Rwanda has been a leading country in COMESA in terms of implementing policies that stimulate development and improve service delivery instated in 2006. To stimulate innovation and creativity in Rwanda's public sector, the Government initiated the Imihigo programme (World Bank, 2018). As an innovation in the public sector, the Imihigo sets development targets to improve the performance of government agencies in dealing with development challenges (Government of Rwanda, 2019). The focus of this innovative programme is to drive economic impact, address local priorities and connect national goals to global development frameworks. Another unique feature of the Imihigo is the emphasis on citizen engagement in development planning, providing them an opportunity to shape policies that directly impact on their lives. The ultimate vision is to facilitate the growth of self-reliant, innovative and economically vibrant communities in Rwanda (Government of Rwanda, 2020). Another notable programme in Rwanda is the partnership between the government and a private technology company. Irembo, to set in motion the digitisation of society, was initially instituted as a financial centre for the payment of government services such as taxes and the transfer of funds to and from public officials. The services have been expanded to include applications for a birth certificate, registration of a driver's license and land titles. It plans to add 100 more e-government services over the next three years, contributing to Rwanda's significant reduction in corruption and the boom in its technology startup sector.

South Africa has emerged as a pioneer in governmental innovation with the establishment of the Centre for Public Service Innovation (CPSI) under the auspices of the Minister of Public Service and Administration. The CPSI's mission is to enhance the quality of public services through the development of innovative, sustainable and responsive models. Facilitating collaboration among public, private and non-governmental entities, the CPSI fosters a culture of innovation within the government sector. Several projects in South Africa have garnered acclaim for their innovative approaches. Notable examples include the Limpopo Provincial Revenue Enhancement Strategy, honoured with the CPSI's 2016 Innovator of the Year award; the Digital Pen for Health initiative by the Department of Health, KwaZulu-Natal, which received the Public Sector Innovation Award in 2014; and the Gauteng Department of Education's Secondary School Improvement Programme (SSIP), recognised with the 2014 United Nations Public Service Award, among others.

In Ghana, progress has been made in digitising government sector operations to enhance efficiency and reduce corruption. Most government services are now offered online rather than manually, supported by initiatives like the Ghana Strengthening Accountability Mechanisms (GSAM) to bolster accountability in the public sector. Notable recognition includes the Ghana Library Authority (GhLA) winning the prestigious 2021 UN Public Service Award for fostering innovation through digital transformation.

Tunisia introduced the Tunisie Digitale 2018 strategic plan to create a favourable digital environment, with government websites available in Arabic and French. The Tunisian Ministry of Communication Technologies is implementing a new single portal for public services, "e-bawaba.tn" alongside the "Mobile ID" programme to provide secure access to digital public services. In healthcare, the CHAM health insurance portal facilitates application submissions and real-time tracking of requests.

The Agriculture Ministry in Zambia launched the Zambia Integrated Agriculture Management Information System (ZIAMIS) to provide agriculture information to all districts, improving decision-making and service delivery. The system enhances access to e-vouchers, e-extension, insurance and more for 1.5-million registered farmers, enabling small-scale farmers to receive inputs from the government or the private sector efficiently.

6.4.3 Partnerships with the Private Sector, Citizens and Civil Society

The engagement of the private sector, individual citizens and civil society organisations as partners in delivering public services (also known as coproduction) can lead to higher user satisfaction and may reduce costs. Partnerships are increasingly used for services traditionally obtained through public procurement. They can offer innovative ways to manage risks and improve efficiency in designing and procuring public services. In addition, partnerships that offer greater user control and ownership can transform the relationship between users and service professionals. For example, Senegal has a policy of rewarding excellence by regularly organising the President's Grand Prize for Science and the Grand President's Award for Innovation. An African exhibition of Research and Innovation in Senegal (SARIS) is regularly organised by the Agence Nationale de la Recherche Scientifique Appliquée (ANRSA) in partnership with all national research and innovation components. The Senegalese Government has always believed innovation is essential for social and economic development, though implementing projects and programmes in organisations may face challenges such as limited technical capacity (Cissé et al,. 2019).

The voices of the people survey, *sauti za wananchi,* revolutionised the participation of citizens in decision-making in Tanzania and Uganda. The survey is carried out using mobile phones, where phone calls are made to nearly 2 000 respondents asking for their opinions and experiences on a range of topics. The findings helped turn a regressive tax into a progressive one. secure access to free healthcare for children, nursing mothers and the elderly and improve official communications on Covid-19 safety measures (Sauti Za Wananchi, 2022).

Benin in partnership with the government of Estonia, has established a digital system enabling access to over 200 public services and created new e-services like national exam results publication, electronic driver's licence exams and e-voting. Senegal's National Digital Public Infrastructure strategy. Senegal Numerique 2025 is a comprehensive strategy to digitalisation the national system. The initiative is designed to leverage information and communication technology (ICT) to enhance public and private sector operations, improve service delivery and promote economic growth. SN2025 is based on the legal and institutional framework, human resources and digital confidence.

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CHAPTER 7
THE 15-YEAR AFRICAN UNION BIBLIOMETRICS ANALYSIS

7.1 INTRODUCTION

Bibliometrics refers to the application of quantitative methods to books and other scientific literature (Pritchard, 1969). This definition translates into the use of mathematical and statistical methods to analyse scientific and technological literature and constitutes a method for measuring the production and dissemination of knowledge. Bibliometrics facilitates the evaluation and benchmarking of research performance by analysing the production of scientific and technological literature. This method allows for comparisons at various levels: a continent can be assessed in relation to the world, a country can be evaluated in relation to a continent or region, an institution can be compared to a country and individual scientists can be measured against their own communities (Okubo, 1997; AOSTI, 2013). As such, bibliometrics is used in research performance evaluation by research directors and administrators, information specialists, librarians, researchers themselves and by many governments globally to assess the impact of their science and technology policies in their innovation systems. Depending on the types of scientific and technological documents analysed, the efficiency of bibliometrics may vary according to scientific domains and fields. For instance, bibliometrics tends to be reliable for the natural sciences but less so for the social sciences and humanities because of the types of outputs in each domain (books versus citation index journal publications). Today, the availability and the use of elaborate databases which contain all types of scientific and technological literature allow now to minimise this bias. When used in conjunction with other relevant indicators from peer judgements and experts' evaluation, bibliometrics helps governments and other stakeholders to decide what research areas to focus on or what strategic projects to support with development agendas.

Bibliometric assessments of the literature on science and technology in Africa is limited and in many cases relate to case studies of individual countries [(Research outputs from relatively small sets of African countries or regions have been analysed in the past (Adams, King and Hook, 2010; Boshoff, 2009, 2010; Pouris and Pouris, 2009; Tijssen, 2007; Toivanen and Ponomariov, 2011; Megnigbeto, 2013; Onyancha and Resenga Maluleka, 2011)]. Also, much of the literature is in English, which may result to an incomplete coverage and underestimation of scientific research in other languages used in Africa. This justifies the need to analyse Africa in a single study for reliable comparison and benchmarking purposes. Such a study was conducted previously by the African Observatory of Science, Technology and Innovation (AOSTI) as the first of a series which is part of the AOSTI's broader mandate to develop and manage science, technology and innovation indicators (AOSTI, 2013).

The present chapter is based on the bibliometric assessment undertaken by AOSTI in collaboration with the Egyptian STI Observatory (ESTIO) on the scientific outputs of the African Union's member countries for the past 15 years. The study uses bibliometric approaches with a variety of output and impact statistics to analyse the scientific production of all 55 Member States and the 8 RECs of the African Union for 15 years, spanning 2008 to 2022.

7.2 METHODOLOGY

Fields of science analysed: the bibliometric data and statistics were produced using Elsevier's Scopus bibliographic database and metrics from both Scopus and SciVal. The six fields of science, as described by Scopus and composed of natural sciences, engineering and technologies, medical sciences, agricultural sciences, social sciences and humanities and their respective subfields, were analysed. Below are the bibliometric indicators produced using the descriptions from the Scopus database and SciVal.

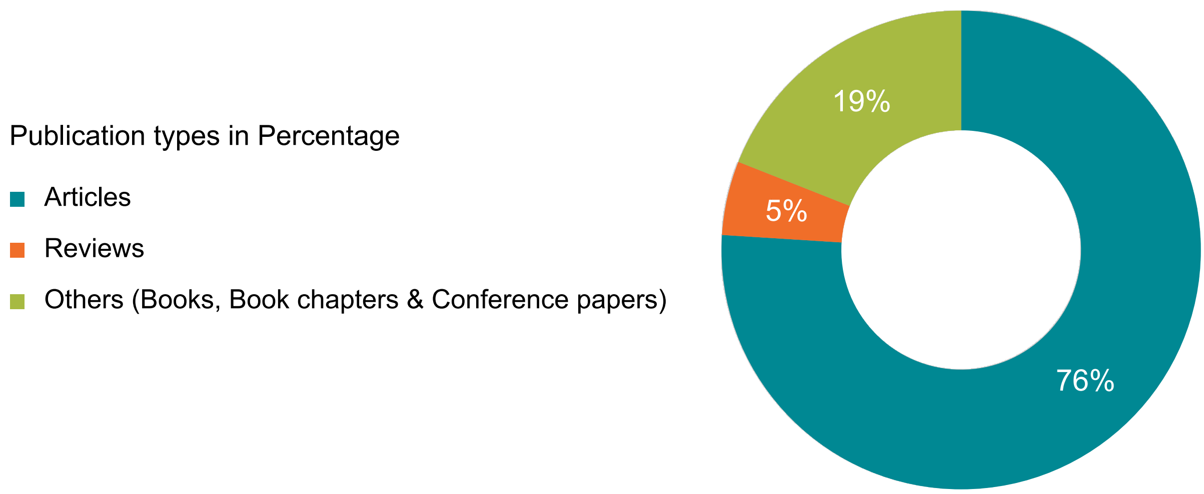
- **Number of papers:** as an indicator of scientific knowledge production, this indicator provides a simple count of scientific papers. The option "All types of publications" used in this study includes research articles, reviews, book chapters and conference proceedings

- **Normalised indicators:** the raw production of papers was normalised by population, GDP per capita and the number of citations to enable fair comparisons between countries. This approach is necessary because larger countries tend to publish more outputs than smaller countries due to their size
- **Growth of scientific production:** this indicator captures the growth of scientific outputs. It is typically calculated over two periods. In the present report, the number of papers published in period 1 is compared with the number published in period 2
- **Research intensity and specialisation index:** this indicator reflects the concentration of papers in given fields, taking the world proportion as the baseline. Thus, the SI indicator translates the research intensity or effort of a given geographic or organisational entity (e.g. a country), in each research area (e.g. field, subfield), relative to the effort of the reference entity (e.g. the world) in the same research area. An index value above 1 (world level) means that a given entity is specialised relative to the reference entity, while an index value below 1 means the opposite
- **Analysis of collaboration:** this is a measure of the number of papers published with other authors in other African Union Member States and elsewhere
- **Citation counts**: this metric evaluates the impact and quality of an article. It is the number of citations received by this article within a specified time frame, through the number of documents indexed by Scopus that cite the article
- **Field-Weighted Citation Impact (FWCI):** this indicator compares the total number of citations received by a researcher's outputs to the average number of citations received by outputs from the same research field. The world average FWCI is 1. Thus, an FWCI of 1 is considered to have the world average impact and an FWCI more than 1 indicates higher than expected citations on the global average for similar publications
- **Top institutions and scientists:** the number of papers produced between 2008 and 2022 was considered to designate the most prolific institutions and scientists for all types of publications combined

7.2.1 Scientific Outputs in the African Union by Types of Publications

The search in the Scopus database for the "Publication all types" option showed that the great majority of the research outputs of Africa are classified as articles (76%) (Figure 7.1). Publications in books and conference proceedings represented 19% of the African scientific literature. In total, 81% of the production consists of articles and reviews combined. These two types – articles and reviews – undergo the most rigorous peer review processes in scientific publishing, making them effective at reflecting the true quality of scientific literature from an entity. However, this bibliometric study combined all types of publications found in the Scopus database to consider the differences in publication preferences between the six fields of science investigated.

Figure 7.1 Shares of publication types in the scientific literature of Africa (2008-2022)



7.2.2 Scientific Outputs of the African Union

For the 15 years covered by this study (2008-2022), the African Union produced 2.8% of the world's total research output for all types of publications combined. The contribution of Africa to the global level reaches 3.3% when articles and reviews are considered only. This is almost double the level (1.8%) of the African outputs (2005-2010) reported previously for the same types of outputs relative to the world (AOSTI, 2013; AIO, 2014). This encouraging trend remains lower than the production of larger economies such as the USA and China, which produce 22.1% and 17.7% of the global scientific output, respectively. Comparisons between Africa and major economies revealed that the production levels of the African Union are six to seven times lower than those of China and the United States, respectively. However, an analysis of Africa's scientific output over the five years from 2018 to 2022 indicated a growth of 67.6% compared to the previous five years (2013-2017). This growth rate is 10 times that of the United States, which saw an increase of 6.7% and slightly higher than China's growth rate of 64.1% during the same period. No negative growth was observed at the level of the individual African Union (Table 1), meaning that the Member States and the African Union are making efforts to increase scientific production over time.

Table 7.1 Scientific production (2008-2022) of African countries, USA, China and the world for all types of publications combined (books, book chapters, articles, reviews and conference proceedings) wit hgrowth (2018-2022/2013-2017)

Entity & overall output 2008-2022		2008	2009	2010	2011	2012	2013	2014
World	46 400 388	2 247 849	2 366 703	2 491 626	2 652 054	2 791 688	2 921 802	2 960 274
China	8 250 253	263 679	309 620	346 478	395 873	417 045	456 811	488 017
United States	10 269 478	574 033	589 277	606 951	629 984	668 521	685 165	674 567
African Union	1 326 164	37 587	43 966	48 500	54 818	60 885	67 287	74 128
Algeria	94 556	2 558	3 172	3 222	3 669	4 378	5 044	5 418
Angola	1 651	36	38	40	51	70	68	101
Benin	7 525	208	250	251	310	357	410	418
Botswana	9 316	343	329	344	440	394	438	535
Burkina Faso	8 449	277	302	314	385	474	415	474
Burundi	969	9	13	32	28	32	43	48
Cameroon	22 394	665	761	768	882	924	1 085	1 235
Cape Verde	576	8	11	14	5	15	28	30
Central African Rep.	813	27	30	29	34	40	39	48
Chad	758	22	32	14	28	25	28	33
Comoros	203	2	4	5	12	5	21	7
Congo	5 760	153	166	215	245	301	366	469
Côte d’Ivoire	7 640	347	325	334	383	394	328	384
Dem. Rep. Congo	3 134	31	52	46	41	65	48	48
Djibouti	368	9	17	14	16	23	18	21
Egypt	302 229	6 896	8 576	9 642	11 408	13 443	15 005	15 843
Equatorial Guinea	244	5	14	11	10	10	9	17
Eritrea	672	24	29	26	35	14	33	30
Ethiopia	52 221	665	767	910	1 083	1 295	1 594	1 924
Gabon	2 914	110	124	112	166	137	161	192
Gambia	2 776	120	118	123	101	135	151	162
Ghana	37 765	619	746	814	1 033	1 212	1 383	1 589
Guinea	1 441	35	31	34	38	41	39	62
Guinea-Bissau	709	20	20	21	30	37	36	58
Kenya	46 084	1 342	1 595	1 769	2 011	2 122	2 420	2 557
Lesotho	1 031	36	34	34	36	46	41	41
Liberia	1 105	11	11	13	25	24	36	36

	2015	2016	2017	2018	2019	2020	2021	2022	Growth
	2 980 811	3 105 305	3 219 998	3 332 974	3 546 452	3 721 635	3 995 987	4 065 230	22.80%
	465 883	505 135	551 679	612 670	715 983	792 422	891 130	1 037 828	64.10%
	693 645	704 365	725 902	738 041	729 697	738 808	770 003	740 519	6.70%
	78 310	88 404	95 543	104 565	117 183	134 328	153 745	166 915	67.60%
	6 128	6 842	7 555	8 539	8 427	8 586	9 948	11 070	50.20%
	105	119	160	119	159	178	177	230	56%
	447	432	533	562	691	747	962	947	74.50%
	494	645	644	839	834	904	1 048	1 085	70.80%
	559	577	569	657	720	778	912	1 036	58.10%
	57	56	61	92	96	135	123	144	22.60%
	1 261	1 428	1 689	1 761	1 963	2 365	2 717	2 890	74.60%
	37	36	48	37	52	72	85	98	92.10%
	46	73	54	71	62	82	84	94	51.10%
	38	45	62	58	73	76	109	115	109.20%
	8	20	13	21	20	21	25	19	53.60%
	453	460	447	496	475	461	498	555	13.20%
	431	429	474	607	691	738	928	847	86.20%
	85	110	175	182	287	510	679	775	422%
	17	21	22	20	19	38	71	42	91.90%
	17 325	19 806	19 947	22 645	26 080	32 477	38 948	44 188	96.90%
	17	27	16	22	20	15	30	21	25.60%
	30	30	45	53	61	77	90	95	123.80%
	2 016	2 270	3 097	3 764	4 962	6 770	9 160	11 944	235.70%
	193	191	198	203	235	221	314	357	42.20%
	175	186	205	159	212	264	331	334	47.90%
	1 834	2 311	2 562	3 141	3 751	4 551	5 487	6 732	144.40%
	118	125	140	103	133	160	198	184	60.70%
	42	61	60	60	61	63	74	66	26%
	2 732	2 955	3 259	3 471	3 989	4 662	5 532	5 668	67.50%
	53	58	67	58	105	111	144	167	125%
	65	93	99	104	124	87	139	238	110.30%

Entity & overall output 2008-2022		2008	2009	2010	2011	2012	2013	2014
Libya	8 139	249	367	520	278	367	494	505
Madagascar	4 917	206	199	194	248	257	302	299
Malawi	10 290	313	311	375	420	439	458	532
Mali	4 240	148	174	183	219	239	219	207
Mauritania	853	26	24	23	33	38	45	47
Mauritius	4 814	115	136	156	139	221	249	246
Morocco	92 193	1 953	2 275	2 566	3 068	3 669	3 956	5 065
Mozambique	6 059	140	160	156	221	214	245	272
Namibia	5 343	103	116	111	146	189	236	270
Niger	2 592	82	110	138	104	110	109	137
Nigeria	135 827	4 085	5 025	5 602	6 247	6 026	6 103	6 372
Rwanda	6 523	76	100	141	164	187	270	302
SaoTome & Principe	103	–	4	4	–	3	2	4
Senegal	11 553	404	415	418	584	644	660	694
Seychelles	854	38	29	32	39	39	49	42
Sierra Leone	2 013	19	36	38	42	47	52	84
Somalia	746	5	4	11	10	6	17	26
South Africa	336 264	10 649	12 018	13 102	14 577	16 460	18 035	20 611
South Sudan	363	1	–	–	5	–	4	26
Sudan	13 499	319	442	531	594	607	758	705
Swaziland	1 893	55	77	120	93	85	91	101
Tanzania	23 436	658	793	890	986	1 019	1 147	1 344
Togo	2 668	81	89	89	113	104	130	163
Tunisia	107 884	3 944	4 424	4 838	5 383	5 673	6 261	6 750
Uganda	25 165	639	767	980	1 077	1 126	1 230	1 353
Western Sahara	11	1	3	2	–	–	–	–
Zambia	8 529	241	224	284	300	344	399	464
Zimbabwe	12 439	314	315	347	366	503	565	686

	2015	2016	2017	2018	2019	2020	2021	2022	Growth
	453	399	489	521	587	737	1 105	1 068	71.70%
	319	308	366	368	371	462	530	488	39.20%
	604	695	776	864	887	1 059	1 304	1 253	75.10%
	260	277	316	316	363	398	442	479	56.20%
	41	61	51	69	83	95	119	98	89.30%
	241	319	377	363	573	510	570	599	82.60%
	4 884	6 331	6 890	7 773	8 926	10 337	11 677	12 823	89.90%
	346	408	468	513	563	704	843	806	97.10%
	322	351	436	498	475	624	734	732	89.60%
	205	178	173	207	246	249	265	279	55.30%
	6 374	7 354	8 378	10 194	12 916	15 263	17 887	18 001	114.70%
	326	391	423	509	594	819	1 061	1 160	141.90%
	3	3	9	7	10	12	13	29	238%
	789	819	853	888	957	1 117	1 120	1 191	38.20%
	57	52	61	55	57	98	108	98	59.30%
	120	169	171	170	184	228	299	354	107.20%
	20	17	44	32	63	91	137	263	372.50%
	21 359	23 788	25 838	27 442	30 071	32 376	34 560	35 378	45.70%
	14	17	21	27	24	46	73	105	235.30%
	678	868	870	1 017	1 148	1 315	1 740	1 907	83.70%
	114	109	149	170	174	175	177	203	59.40%
	1 424	1 544	1 697	1 803	2 146	2 371	2 740	2 874	66.70%
	185	172	163	220	237	262	299	361	69.60%
	7 480	8 332	9 143	8 561	8 488	8 706	9 413	10 488	20.20%
	1 481	1 644	1 884	1 914	2 150	2 541	3 126	3 253	71%
	3	–	–	–	–	–	1	1	66.70%
	510	616	695	653	695	912	1 043	1 149	65.80%
	695	858	1 016	1 099	1 104	1 296	1 556	1 719	77.30%

7.2.3 Country Ranking by Raw and Normalised Scientific Outputs

The top five countries with the greatest production in the previous analysis of the African Union (AOSTI 2013) hold their raw production ranking in the present study, with South Africa (1st), Egypt (2nd), Nigeria (3rd), Tunisia (4th) and Algeria (5th). The normalisation of raw output allows for fair comparisons between the largest and smallest countries in evaluations, as relying solely on raw scientific output often benefits larger countries. As shown in Table 7.1, when the total raw production is normalised per capita, per GDP and number of citations of the publications, the ranks of countries vary. Only four countries (South Africa, Egypt, Tunisia and Morocco) remain in the top 10 for the four measures (Raw, per capita, per unit GDP and citations). The implications of the top 10 rankings in all normalised categories for South Africa, Egypt, Tunisia and Morocco need further investigation. It remains to be seen whether these four countries are making efforts that are proportional to their characteristics compared to other AU Member States.

Among the top 10, Nigeria has the largest deviation of ranking by normalised data, coming 21st for output per capita and 33rd for output per GDP unit (Table 7.2). Countries which integrate the top 10 in ranking by one or more normalised output categories include Botswana, The Gambia, Mauritius, Seychelles, Namibia and Malawi. This shows the importance of data normalisation in bibliometric studies in various instances of data interpretation. A variety of indicators, such as the number of researchers, Full-time equivalent (FTE) data and gross domestic expenditure on R&D (GERD), can be utilised for normalisation purposes.to assess the efficiency of scientific production at the national, regional and continental levels. Ongoing efforts of the African Union through the African Science, Technology and Innovation Initiative (ASTII) of the AUDA-NEPAD are producing data on some of these key input indicators. Therefore, it is crucial to sustain these efforts through country capacity building and empowering dedicated AU offices such as AOSTI to collect and to use the needed indicators.

Table 7.2 Ranking of the 55 AU Member States – raw and normalised scientific production (2008-2022)

Countries and ranking by raw scientific production (total nbr of papers)		Country ranking by normalised scientific production		
		No. of citations of papers	[a]By no. of papers/ capita	[b]By nbr of papers per billion GDP (nominal)
South Africa*	1	1	3	3
Egypt*	2	2	6	6
Nigeria***	3	3	21	33
Tunisia*	4	4	1	1
Algeria**	5	6	8	12
Morocco*	6	7	7	5
Ethiopia***	7	8	29	21
Kenya***	8	5	17	22
Ghana**	9	9	13	9
Uganda**	10	10	23	7
Tanzania	11	11	31	32
Cameroon	12	12	18	11
Sudan	13	17	35	36
Zimbabwe	14	16	19	17
Senegal	15	20	20	20
Malawi	16	13	24	4
Botswana	17	19	5	14
Zambia	18	14	28	34
Burkina Faso	19	25	30	15

Countries and ranking by raw scientific production (total nbr of papers)		Country ranking by normalised scientific production		
		No. of citations of papers	[a]By no. of papers/ capita	[b]By nbr of papers per billion GDP (nominal)
Libya	20	23	12	41
Côte d'Ivoire	21	24	36	44
Benin	22	18	22	18
Rwanda	23	21	25	13
Mozambique	24	15	42	28
Congo	25	22	16	24
Namibia	26	27	9	19
Madagascar	27	29	44	29
Mauritius	28	30	4	26
Mali	29	28	40	38
Dem. Republic Congo	30	32	54	50
Gabon	31	31	11	43
Gambia	32	26	14	2
Togo	33	34	34	30
Niger	34	35	48	40
Sierra Leone	35	33	38	10
Swaziland	36	39	10	25
Angola	37	40	50	52
Guinea	38	38	47	48
Liberia	39	36	39	35
Lesotho	40	44	27	23
Burundi	41	41	49	31
Seychelles***	42	37	2	8
Mauritania	43	47	43	47
Central Afr. Republic	44	43	46	27
Chad	45	45	51	49
Somalia	46	49	52	46
Guinea-Bissau	47	42	32	16
Eritrea	48	48	41	NC
Cape Verde	49	46	15	37
Djibouti	50	51	33	45
South Sudan	51	52	53	NC
Equatorial Guinea	52	50	45	51
Comoros	53	53	37	42
Sao Tome & Principe	54	54	26	39
Western Sahara	55	55	55	NC

Source: Scopus – All publication types (Books, Book chapters, Articles, Reviews and Conference papers)

Notes:
(*) Countries that are in the top 10 for the 4 categories of ranking (raw production, production normalised by capita and production normalised by GDP)
(**) Countries that stay among the Top 10 for only 3 categories of the ranking
(***) Countries that are in the Top 10 for only 2 categories of the ranking
a World population prospects 2022 (UN Population Division)
b GDP (Nominal). World Development Indicators 2022 (World Bank)

7.2.4 Contribution of Fields of Science to the Scientific Output of Africa

The coverage of each field of science in the global and African scientific literature is captured in Figures 7.2 and 7.3. The field of natural sciences has the biggest share of Africa's scientific production, followed by the field of medical sciences and to a lesser extent by the field of engineering and technologies. This follows the distribution at the global level where natural sciences, medical sciences and engineering and technologies also come in the first, second and third positions, respectively. The African Union displays 2.4% and 5.2% more focus than the world in natural sciences and in medical sciences, respectively, but Africa is slightly behind the world in engineering and technologies by 1.8%. The humanities field is the least represented in African scientific literature, showing a 15% gap compared to the global average. The African Union appears to place little emphasis on Humanities research. It is important to highlight that the underrepresentation of the Humanities in bibliometric studies is often due to a preference for publishing books in this field. This study addresses that issue by including both books and book chapters in its analysis.

Figure 7.2 Distribution of the global scientific outputs by fields of science (2008-2022), also known as fields of R&D (FoRD) in the Frascati Manuals (OECD, 2015)

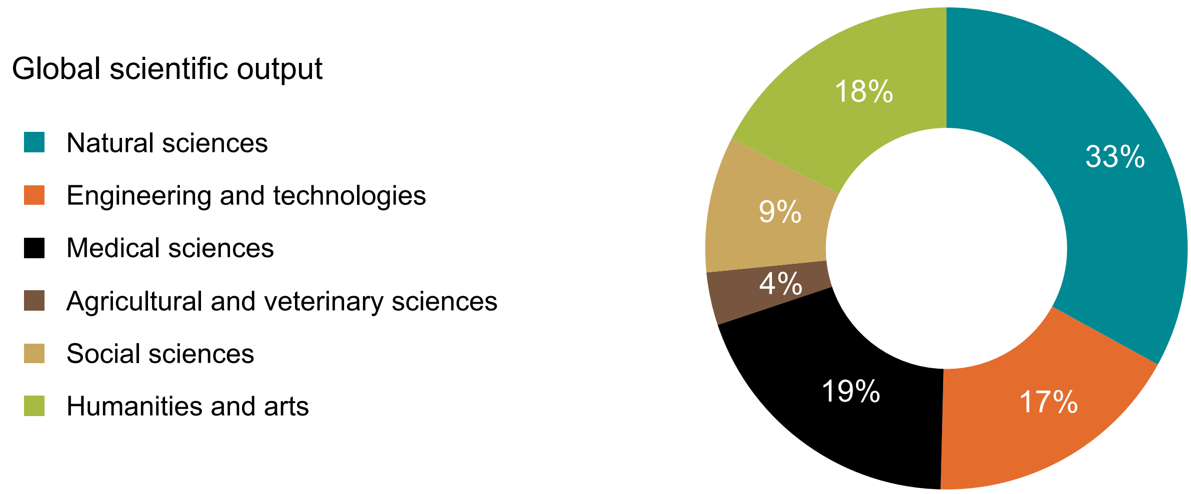
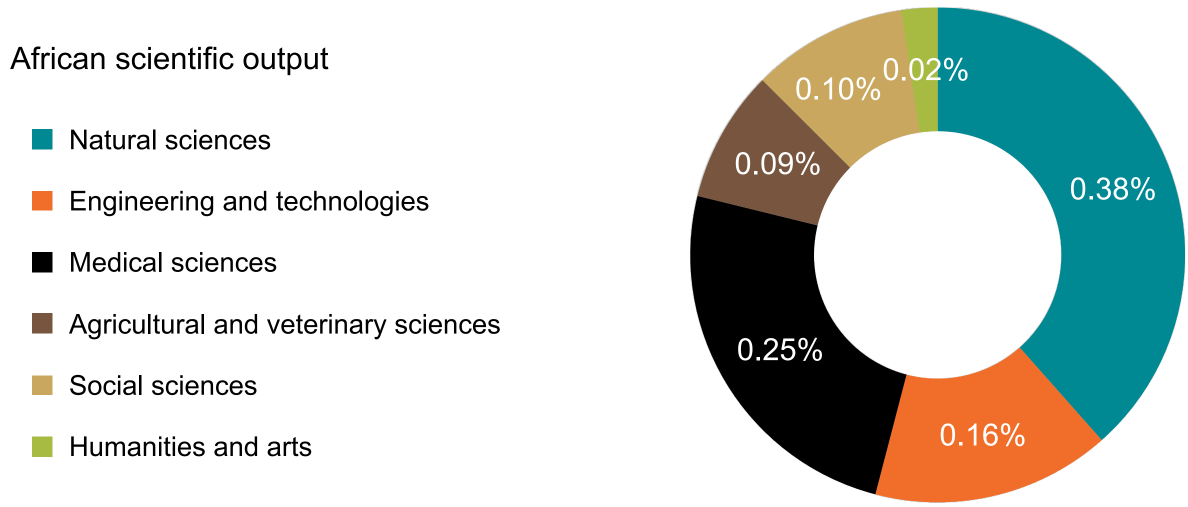


Figure 7.3 Distribution of the African scientific outputs by fields of science (2008-2022), also known as fields of R&D (FoRD) in the Frascati Manuals (OECD, 2015)



The analysis at the level of the Regional Economic Communities (RECs) of the African Union also showed that natural sciences are the leading field, followed by the field of medical science, as shown in Figures 7.4, 7.5 and 7.6 for the three RECs. The coverages of the field of engineering and the field of humanities displayed notable variations between the RECs; The Arab Maghreb Union (AMU) showed the biggest interest in engineering and technologies, with positive differences of 7.4% and 9.2% relative to the world and Africa, respectively. The levels of contribution displayed by the field of Humanities by the RECs varied from 0.04% to 0.32%. This is more than 16% lower than the global level and reflects the low level of contribution observed at the continental level for this field. The low level of representation of the field of Humanities in the African scientific literature needs to be researched further and addressed. Indeed, Africa, as the cradle of humankind, has much to offer and gain from its arts, history, archaeology, philosophy and other subfields within the humanities.

Figure 7.4 Distribution of the scientific outputs of the ECOWAS region by fields of science (2008-2022)

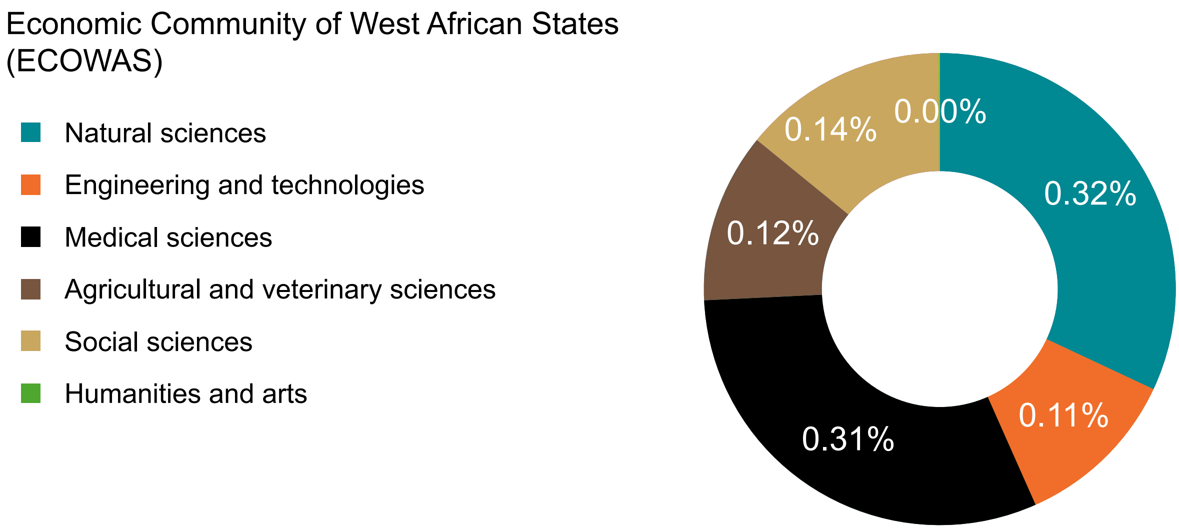


Figure 7.5 Distribution of the scientific outputs of the SADC region by fields of science (2008-2022)

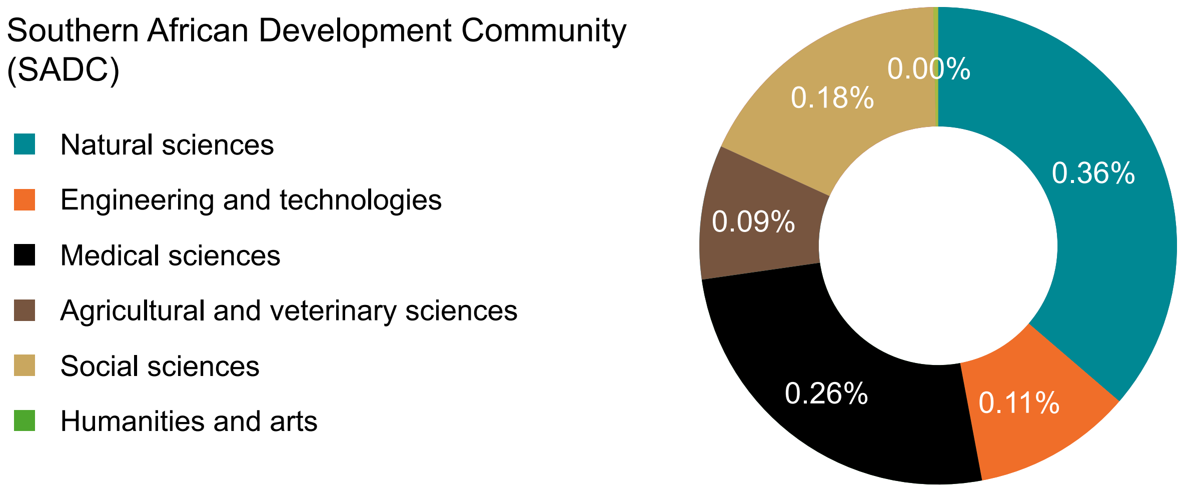
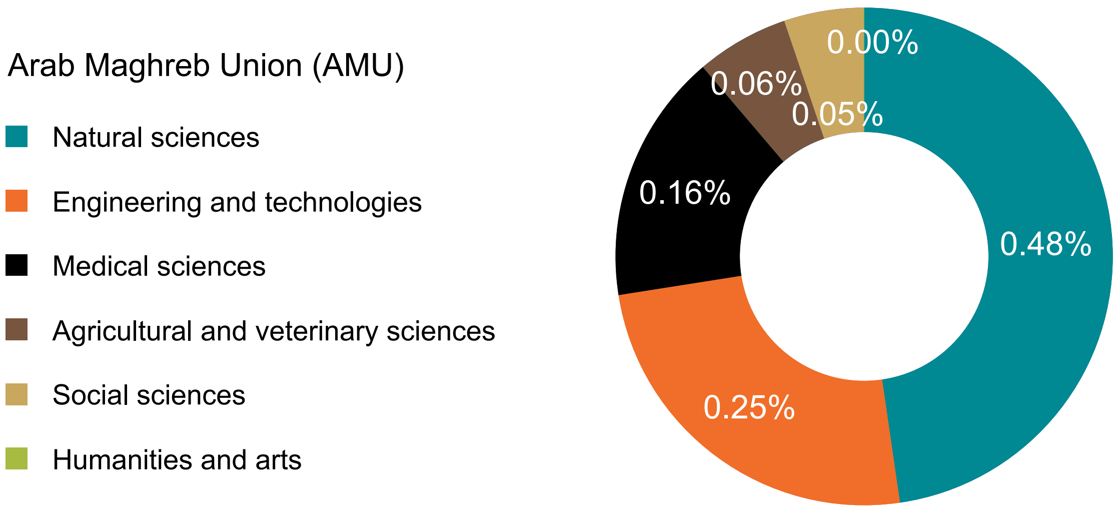


Figure 7.6 Distribution of the scientific outputs of the Arab Maghreb Union (AMU) region by fields of science (known as fields of research, FoRD) (2008-2022)



7.3 SPECIALISATION OF THE AFRICAN UNION AND RECS IN SCIENTIFIC PRODUCTION

The specialisation or research intensity (RI) indicates whether the level of focus/effort produced by a country in each field of science is higher than the global (world) average focus/effort in that field of science (RI > 1 or >100%) or lower-than-global effort (RI < 1 or <100%). The colours displayed in Table 7.3 are the results of the combination of the RI indicator with the indicator of the quality/impact (or uptake by the scientific community) of the production of a country or a region. The integration of the RI with the production quality indicator reveals an entity's strengths and weaknesses, as indicated by the colour legend below Table 7.3.

The analyses indicate that the natural sciences represent a significant strength of the African Union (AU) as an entity. Among the various science fields, agricultural science stands out, as the AU and its Regional Economic Communities (RECs) collectively demonstrate a research focus that exceeds the global average. This focus is crucial for addressing food and nutrition security to feed Africa's growing population, as well as for developing the continent's agroindustry to enhance value addition. As shown in Table 7.3, this trend is positive at both continental and regional levels.

In contrast, the AU and the seven RECs need to improve their efforts in engineering and technology. Currently, their research intensity in these areas falls below the global average. The Arab Maghreb Union (AMU) is the only African entity with a notable research intensity that is 39% above the world average. Given the significance of engineering and technology for the ongoing industrial revolution, Africa must tackle this issue. One potential solution is to strengthen collaboration between the AMU and the other RECs in these fields. Transitioning away from economies based on the export of raw commodities is a key component of the Accelerated Industrial Development for Africa Action Plan. Achieving this goal will require a strong emphasis on engineering and technology in African countries. The field of humanities also exhibits a significantly lower research intensity than the global average for the AU and the seven RECs, except for the Southern African Development Community (SADC). Given the humanities' minimal contribution to the publication pool of the RECs (only 0.32% for the SADC), this area warrants further investigation.

Table 7.3 Strengths, weaknesses and areas of mixed performance of the African Union and its RECs

Entity	Natural sciences	Engineering & Technologies	Medical Sciences	Agricultural Sciences	Social Sciences	Humanities
African Union						
AMU: Arab Maghreb Union						
CEN-SAD: Community of Sahel-Saharan States						
COMESA: Common Market for Eastern and Southern Africa						
EAC: East African Community						
ECCAS: Economic Community of Central African States						
ECOWAS: Economic Community of West African States						
IGAD: Intergovernmental Authority on Development						
SADC: Southern African Development Community						

Notes: Evaluations are done relative to the world average, which is the reference set at 1. Data behind the colours can be expressed in indices or percentages. Below is the legend with the meanings of the Colour code.

Strength	The focus (RI) and the impact (citation counts) of the entity are higher than the world averages in that field
Weakness	The focus (RI) and the impact (citation counts) of the entity are both lower than the world averages in that field
Lower impact	The impact (citation counts) of the entity is lower than the world average impact in that field, while the focus is higher than the global average
Lower focus	The focus (RI) of the entity is lower than the world average focus in that field, while the citations are lower than the global average

7.3.1 Analysis of the Collaboration of the African Union in Scientific Production

Collaboration in science is crucial to answer challenges posed by the complexity of research topics through the exploitation of collective knowledge and resources. Among the types of collaboration taken individually in this study, international collaboration has the biggest share (Figure 7.7) at 49%. Each type of collaboration, as captured in Figure 7.7, has its own importance, whether the research issue to be addressed is of local, regional or global importance. With the increasing globalisation of research, international collaboration is seen as the one that gives the highest impact in scientific publications. However, as the national research capacity and resources increase (human, infrastructure and funding), national autonomy also increases to lower levels of international collaboration. This is shown in Table 7.4, where the average level of international collaboration in Africa is significantly higher than the levels found in larger economies. When the top 6 biggest producing countries of Africa (Table 7.4) are pulled together, their average rate of international collaboration (43%) is lower than the average rate of the African continent, but almost two times lower than the international collaboration rate of the remaining African countries which stands at 80.5%, with a variation from 52.4% (Ethiopia) to 97.5% (Guinea Bissau).

Most of the international collaboration rates of Africa revealed in this work are driven by Africa's collaboration with countries outside Africa. Indeed, the intra-Africa collaboration rate remains under 10%, as also shown in the previous analysis of the 2005-2010 scientific production (AOSTI, 2013). This calls for action to increase intra-Africa collaboration in science. The high level of international collaboration in Africa is partly due to low levels of infrastructure, human resources and funding for R&D on the continent. The overwhelming reliance on external resources for African scientific research has a negative impact on R&D agenda setting in Africa. This also justifies the ASTII initiative, which aims to gather data on R&D for the continuous assessment of Africa's continental target of dedicating 1% of GDP to R&D.

Figure 7.7 Geographical collaborations of the African Union for all publications

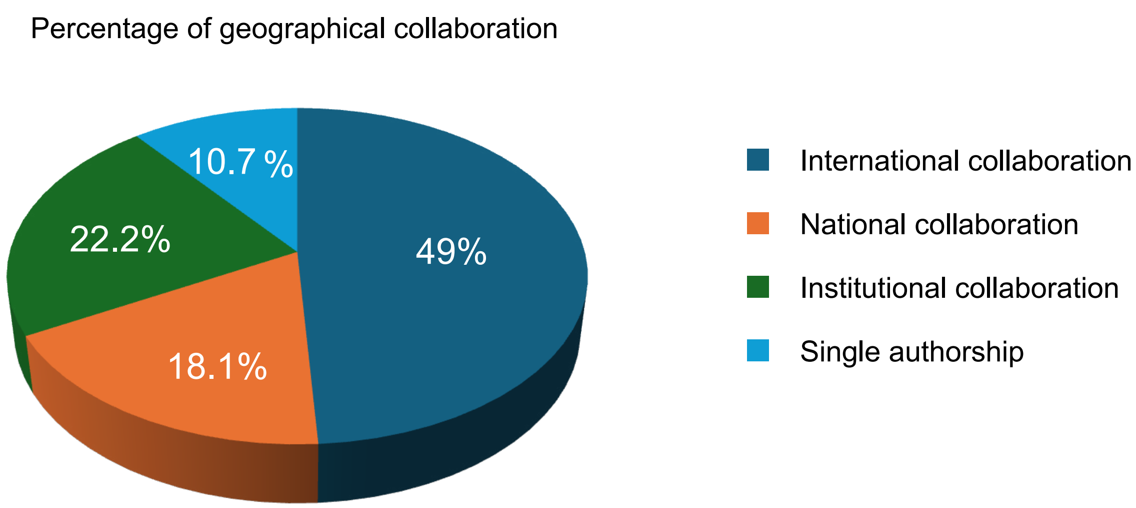


Table 7.4 Average international collaboration rates of Africa and of entities outside of Africa, based on number of papers published (all types of publications) 2008-2022

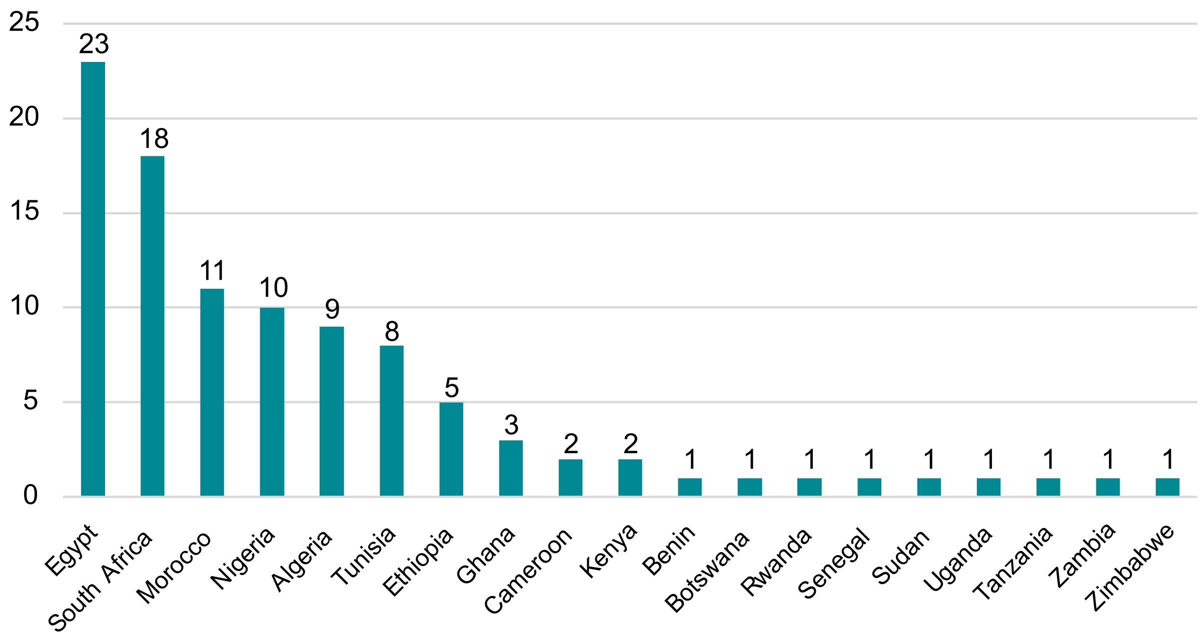
Africa	**49%**
BRICS – Brazil. Russia. India. China. South Africa	20.6%
China	19.6%
Malaysia	39.9%
India	18.3%
Russian Federation	24%
South Korea	27.8%
United States	31.3%
Brazil	30%
*Average for the top 6 African countries (in number papers produced)	43%
Average of the remaining African countries (without the top 6 countries)	80.5%

Note: *The top 6 highest producing countries in Africa in raw number of papers are:
Tunisia, Algeria and Morocco (refer to Table 7.3).

7.3.2 Leading Academic Institutions of Africa

The analysis of the top academic institutions is meant to provide collaboration opportunities to other African institutions in the specific areas of expertise of the top institutions. The analysis showed that the top six most productive countries (Egypt, South Africa, Morocco, Nigeria, Tunisia and Algeria) harbour 79 of the 100 top institutions (Figure 7.8). This ranking probably varies if the data is normalised by the number of citations to take in account the quality (the frequency of use of the papers by the scientific community).

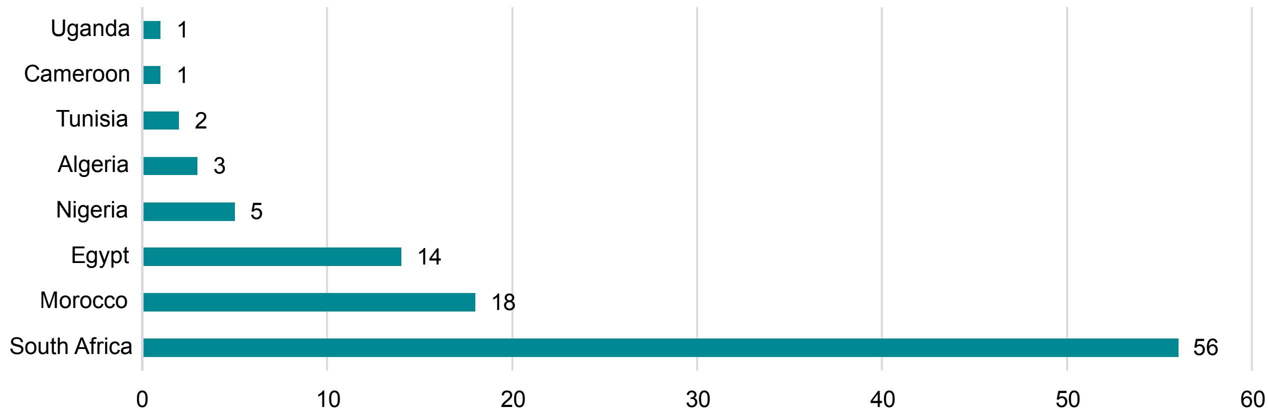
Figure 7.8 African countries harbouring the top 100 academic institutions



7.3.3 Analysis of Leading Scientists of Africa

The most highly productive countries in terms of the number of papers are concentrated in only eight countries out of the 55 member countries of the African Union, with South Africa having the lion's share, at 56 scientists among the top 100 scientists of the continent (Figure 7.9). Creating a catalogue of top scientists, like what is done for leading institutions, can help African organisations and institutions foster collaborations with these esteemed individuals. It is recommended to evaluate the quality of these scientists' papers to standardise their ranking.

Figure 7.9 African countries harbouring the top 100 most productive scientists of Africa for number of papers produced (all publication types 2008-2022)



7.4 RECOMMENDATIONS

Considering the above findings, it is recommended to:

- Increase the visibility of the AU's scientific production
- Monitor and evaluate Africa's scientific production
- Address gaps in fields of science that are essential to today's competitive knowledge economy
- Boost intra-African cooperation in S&T while maintaining strong collaboration outside Africa
- Sustain the current growth trend of Africa's scientific production by adequate policy measures.

7.5 CONCLUSION

The output of the African Union is relatively small, but growing rapidly, at a rate 10 times higher than that of the United States and slightly higher than that of China. The study showed that 76%, 6% and 18% of the scientific production of the African Union for the 15 years (2008-2022) is composed of research articles, reviews and others (books, book chapters and conference papers), respectively. Among the six fields of science analysed, natural sciences constitute the strength for Africa as a whole, while in the field of engineering and technologies, Africa is below the global intensity but matches the global level of impact. The Covid-19 pandemic has presented significant challenges for the continent of Africa, particularly in the field of medical sciences. While Africa's quality in this field is 8% above the global average, its research intensity is 2% below that average, highlighting a need for focused attention. Additionally, all Regional Economic Communities (RECs) of the African Union (AU) demonstrate a lack of strength in engineering and technology, which are crucial fields for industrialisation and the various strategies outlined by the AU, RECs and individual countries. A programme to increase research intensity and quality in engineering and technologies could help the African industrialisation strategies and action plans. The picture of collaboration is largely dominated by international collaboration outside Africa. Enhancing cooperative research at the national, regional and continental levels is essential for achieving a greater impact on domestic issues. When ranking scientific production, fields of specialisation, collaboration patterns and profiling top institutions and academies, the observations at the national and regional levels vary but generally align with trends seen at the African Union (AU) level. Conducting a detailed profiling of countries and Regional Economic Communities (RECs) will provide valuable information for policy-making and decision-making. Overall, the trend of scientific advancement within the AU is quite promising, although further investigation into specific areas at a more detailed level is necessary. This can be facilitated upon request and in collaboration with the African Observatory for Science, Technology and Innovation (AOSTI).

7.6 REFERENCES

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CHAPTER 8
CONCLUSIONS – CHALLENGES, OPPORTUNITIES AND RECOMMENDATIONS

The journey towards sustainable industrialisation in Africa, as elaborated within this Draft AIO2023 Work-in-Progress report, is multifaceted and dynamic, necessitating a concerted and strategic approach that aligns with the African Union's Agenda 2063 aspirations. This report provides a comprehensive analysis across several chapters, each delving into the critical aspects required for a transformative industrialisation pathway that leverages Africa's rich resources, burgeoning human capital and burgeoning technological landscape.

Central to our findings is the imperative for cohesive regional strategies and a unified vision across Regional Economic Communities (RECs). These strategies must foster the establishment of regional industrial hubs and invest significantly in upgrading and expanding essential infrastructures, such as transport, energy and digital communications. Such foundational enhancements will catalyse industrial activities and underpin the broader objectives of economic transformation and integration.

Furthermore, this report accentuates the critical role of Science, Technology and Innovation (STI) as the cornerstone of industrial development. It recommends an escalated commitment to STI through increased public and private investments in research and development (R&D), which are pivotal for fostering innovation and technological adaptation. The call for enhanced educational systems, particularly focusing on science, technology, engineering and mathematics (STEM) disciplines, aims to cultivate a workforce that is not only skilled but capable of driving innovation and technological advancement.

The involvement of the private sector emerges as a recurring theme throughout the report, recognised as indispensable for achieving industrial scale and efficiency. Policies that stimulate private sector engagement through incentives, supportive regulatory frameworks and public-private partnerships are essential for mobilising the necessary investment, knowledge and expertise.

As we propel forward, it is imperative to harness the potential of emerging technologies and sectors identified within the report as having significant growth prospects. These sectors present opportunities for Africa to leapfrog traditional industrial pathways and embrace a future that integrates technological advancement with sustainable development practices.

Therefore, looking forward to the post-Covid19 African Innovation Outlook reports (AIO-V or AIO-2025), let us bear in mind the options below in the efforts of using STI core indicators to help in evidence-based decision-making that will translate African challenges into opportunities.

1) Africa offers a unique innovation ecosystem, considering diverse challenges and opportunities that create a unique environment for innovation and emerging technologies in the current 4th and 5th industrial revolutions (4IR and 5IR). It goes from mobile technology to renewable energy solutions and ethical genome editing in both health and agriculture. Africa's innovation landscape has increasingly drawn global attention as a driver of new approaches to both local and global problems
2) Africa is showing some emerging trends that are enabling more AU Member States to transition from least developed countries (LDCs) to middle-income economies by 2034, despite 33 (73%) of its countries being classified as LDCS in 2021 among the 45 worldwide in that category. Though this figure implies that 60% (33 out of 55) of AU Member States were LDCs in 2021, the continent projects key trends, such as digital transformation, fintech, sustainable development and agriculture technology, where African innovators are making strides. In December 2024, the LDCs went down to 44 LDCs with 72% representing 32 AU Member States (Angola, Benin, Burkina Faso, Burundi, Central African Republic, Chad, Comoros, Democratic Republic of the Congo, Djibouti, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Rwanda, Senegal,

Sierra Leone, Somalia, South Sudan, Sudan, Togo, Uganda, United Republic of Tanzania and Zambia); 18% in Asia (Afghanistan, Bangladesh, Cambodia, Lao People's Democratic Republic, Myanmar, Nepal, Timor-Leste and Yemen), 2% in the Caribbean (Haiti) and 6.8% in the Pacific (Kiribati, Solomon Islands and Tuvalu)

3) Africa is actively promoting collaboration between the government, business enterprises (private sector) and global partners through innovative activities. This is evident in the roles played by public policies and investments from the business sector in fostering innovation and building partnerships with development partners and supporters of Africa. Organisations such as ASTII, AOSTI and STI desks within regional economic communities (RECs), along with ministries responsible for science, technology and innovation (STI) and various think tanks at national, regional, continental and international levels – such as universities, research networks and international development cooperation agencies – are working to create innovation-friendly policies and environments. This effort is crucial for accelerating growth across various sectors
4) Africa is predominantly blessed with a substantial young population, which is increasingly becoming a catalyst for change. This demographic is viewed as a significant asset, providing a large pool of entrepreneurial talent that supports the goals of the Energise Africa Initiative (Pillar 2). The youth bring fresh perspectives to global challenges and are driving innovation through new technologies and solutions. Their adaptability to ongoing digital changes makes them well-suited to navigate the evolving landscape
5) Africa can translate its challenges into opportunities by acknowledging the factors that hamper innovation (access to funding, infrastructure, critical skills, etc.) to boost the continent's emerging markets and natural endowments and mineral resources
6) Africa is emerging as a positive player in global impact, as research and innovation transform the continent and influence global markets for strategic and rare earth minerals, fostering cross-border collaborations with Africa's home-grown and innovative solutions

In conclusion, the AIO-204 report not only outlines the challenges but also charts a strategic path forward. It calls for a holistic and integrated approach involving all stakeholders – governments, industry, academia and international partners – to transform these insights and recommendations into effective actions and measurable outcomes. By embracing this collaborative model, Africa can ensure its place in a future where industrialisation drives sustainable growth, economic diversification and improved well-being for all its citizens. The task is complex and requires persistent dedication, but it is within the realm of possibility with collective resolve and strategic action.

RECOMMENDATIONS

Chapter 2: Industrialisation, Innovation and Development in Africa

1. **Promote regional industrial hubs:** develop regional industrial hubs based on local resource endowments and existing industrial capacities to drive localised economic growth and sustainable development
2. **Enhance infrastructure investments:** invest in critical infrastructure such as transportation, energy and digital connectivity to support industrial activities and enhance productivity
3. **Advance smart manufacturing pathways:** facilitate the gradual transition from traditional production to Industry 4.0 by supporting pilot smart factories, industrial clusters and digital upgrading of SMEs

Chapter 3: Africa's STI Landscape for Accelerated Industrialisation

1. **Strengthen STI policies:** implement comprehensive Science, Technology and Innovation (STI) policies that support research, development and innovation across key sectors, particularly focusing on technological adaptation and local innovation
2. **Invest in human capital development:** increase funding for education, particularly in science, technology, engineering and mathematics (STEM) to build a robust workforce capable of supporting sustainable industrialisation
3. **Build industrial digital skills:** establish targeted programmes for advanced digital and engineering skills (automation, AI, data analytics, additive manufacturing) to prepare Africa's workforce for smart manufacturing

Chapter 4: Accelerating Industrialisation in Africa Through STI Policies

1. **Policy harmonisation across RECs:** encourage harmonisation of STI and industrial policies across Regional Economic Communities (RECs) to create a cohesive framework that supports industrialisation and market integration
2. **Promote private sector engagement:** develop policies that foster private sector participation and investment in industrial and STI initiatives, leveraging public-private partnerships to enhance industrial growth
3. **Create enabling oolicies for industry 4.0 (4IR):** adopt regulatory frameworks and incentives that encourage the integration of smart technologies in manufacturing, logistics and energy, while ensuring sustainability and inclusiveness

Chapter 5: Research and Experimental Development

1. **Boost R&D funding:** substantially increase the allocation of national budgets towards research and experimental development, focusing on sectors that have the highest potential for technological advancements and economic returns
2. **Establish centres of excellence:** Set up centres of excellence in key technological areas to concentrate skills, resources and research capabilities, fostering innovation and advanced scientific research
3. **Promote applied research for industrial transformation:** support R&D in applied industrial technologies such as advanced materials, automation, renewable energy integration and digital manufacturing to close the gap between research and production

Chapter 6: Innovation and Emerging Issues

1. **Support emerging sectors:** identify and support emerging sectors with potential for rapid growth and value addition through targeted STI initiatives and innovation incentives
2. **Adopt and adapt emerging technologies:** promote the adoption and adaptation of emerging technologies such as AI, IoT and robotics in industrial processes to improve efficiency and competitiveness
3. **Develop smart manufacturing ecosystems:** foster collaboration among governments, universities and industry to create innovation hubs, demonstration labs and industrial test beds for experimenting with smart manufacturing solutions tailored to African contexts

ANNEX TABLES

ANNEX 1 – R&D PERSONNEL DATASET

1.1 BENIN 2022

Table 1.1.1 Distribution of R&D personnel (HC) by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	1 348	NA	476	872	NA
Researchers	808	NA-	121	687	NA
Technicians	249	NA	114	135	NA
Support Staff	291	NA	241	50	NA
Total Female	293	NA	85	208	NA
Researchers	177	NA	25	152	NA
Technicians	76	NA	28	48	NA
Support Staff	40	NA	32	8	NA

Table 1.1.2 Full-time equivalent for R&D personnel by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	877.9	NA	429.9	448.0	NA
Researchers	446.0	NA	91.7	354.3	NA
Technicians	164.5	NA	97.2	67.3	NA
Support Staff	267.4	NA	241.0	26.4	NA
Total Female	186.0	NA	78.0	108.0	NA
Researchers	102.4	NA	20.8	81.6	NA
Technicians	46.2	NA	25.2	21	NA
Support Staff	37.4	NA	32.0	5.4	NA

Table 1.1.3 R&D personnel (HC) by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	1 348	NA	476	872	NA
ISCED 8	612	NA	48	564	NA
ISCED 7	282	NA	77	205	NA
ISCED 6	169	NA	94	75	NA
ISCED 5	259	NA	253	6	NA
ISCED 4 & Below	26	NA	4	22	NA
Total Female	293	NA	85	208	NA
ISCED 8	124	NA	7	117	NA
ISCED 7	82	NA	19	63	NA
ISCED 6	49	NA	24	25	NA
ISCED 5	38	NA	35	3	NA
ISCED 4 & Below	0	NA	0	0	NA

Table 1.1.4 FTE for R&D personnel by Level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	882.1	NA	429.0	453.1	NA
ISCED 8	329.0	NA	39.0	290.0	NA
ISCED 7	161.7	NA	54.0	107.7	NA
ISCED 6	131.6	NA	91.2	40.4	NA
ISCED 5	247.8	NA	244.6	3.2	NA
ISCED 4 & Below	12.1	NA	0.2	11.9	NA
Total Female	189.1	NA	78.2	110.9	NA
ISCED 8	71.7	NA	6.3	65.4	NA
ISCED 7	43.8	NA	14.8	29.0	NA
ISCED 6	36.9	NA	24.0	12.9	NA
ISCED 5	34.5	NA	32.9	1.6	NA
ISCED 4 & Below	2.2	NA	0.2	2.0	NA

Table 1.1.5 R&D personnel (HC) by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	1 348	NA	476	872	NA
Natural Sciences	102	NA	NA	102	NA
Engineering & Technology	73	NA	NA	73	NA
Medical & Health Sciences	52	NA	NA	52	NA
Agricultural & Vet. Sciences	576	NA	408	168	NA
Social Sciences	82	NA	16	66	NA
Humanities & Arts	91	NA	NA	91	NA
Not elsewhere classified	372	NA	52	320	NA
Total Female	293	NA	85	208	NA
Natural Sciences	32	NA	NA	32	NA
Engineering & Technology	15	NA	NA	15	NA
Medical & Health Sciences	18	NA	NA	18	NA
Agricultural & Vet. Sciences	123	NA	74	49	NA
Social Sciences	10	NA	2	8	NA
Humanities & Arts	10	NA	NA	10	NA
Not elsewhere classified	85	NA	9	76	NA

Table 1.1.6 FTE for R&D personnel by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	880.4	NA	429.9	450.5	NA
Natural Sciences	55.8	NA	0.0	55.8	NA
Engineering & Technology	31.5	NA	0.0	31.5	NA
Medical Sciences	34.3	NA	0.0	34.3	NA
Agricultural & Vet. Sciences	506.7	NA	408.0	98.7	NA
Social Sciences	44.9	NA	6.3	38.6	NA
Humanities & Arts	46.3	NA	0.00	46.3	NA
Not elsewhere classified	160.9	NA	15.6	145.3	NA
Total Female	188.2	NA	78.0	110.2	NA
Natural Sciences	19.2	NA	0.0	19.2	NA
Engineering & Technology	6.3	NA	0.0	6.3	NA
Medical & Health Sciences	10.6	NA	0.0	10.6	NA
Agricultural & Vet. Sciences	101.1	NA	74.0	27.1	NA
Social Sciences	8.4	NA	1.3	7.1	NA
Humanities & Arts	6.2	NA	0.0	6.2	NA
Not elsewhere classified	36.3	NA	2.7	33.6	NA

Table 1.1.7 R&D personnel (HC) by age and sex

Age	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	1 348	NA	476	872	NA
Under 25 years	43	NA	NA	43	NA
25-34 Years	260	NA	26	234	NA
35-44 Years	509	NA	183	326	NA
45-54 Years	334	NA	151	183	NA
55-64 Years	184	NA	115	69	NA
65 Years and more	18	NA	1	17	NA
Total Female	293	NA	85	208	NA
Under 25 years	17	NA	NA	17	NA
25-34 Years	97	NA	11	86	NA
35-44 Years	114	NA	40	74	NA
45-54 Years	43	NA	20	23	NA
55-64 Years	22	NA	14	8	NA
65 Years and more	NA	NA	NA	NA	NA

Table 1.1.8 FTE for R&D personnel by age and sex

Age	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	880.4	NA	429.9	450.5	NA
Under 25 years	16.6	NA	26.0	16.6	NA
25-34 Years	166.8	NA	173.9	140.8	NA
35-44 Years	330.4	NA	141.3	156.5	NA
45-54 Years	237.1	NA	88.4	95.8	NA
55-64 Years	121.2	NA	0.3	32.8	NA
65 Years and more	8.4	NA		8.1	NA
Total Female	189.8	NA	78.6	111.2	NA
Under 25 years	5.3	NA	NA	5.3	NA
25-34 Years	62.7	NA	11.0	51.7	NA
35-44 Years	76.1	NA	39.3	36.8	NA
45-54 Years	34.5	NA	20.6	13.9	NA
55-64 Years	11.3	NA	7.7	3.6	NA
65 Years and more	NA	NA	NA	NA	NA

Table 1.1.9 Researchers (HC) by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	808	NA	121	687	NA
ISCED 8	599	NA	48	551	NA
ISCED 7	180	NA	67	113	NA
ISCED 6	26	NA	3	23	NA
ISCED 5	3	NA	3	0	NA
ISCED 4 & Below	0		0	0	
Total Female	177	NA	25	152	NA
ISCED 8	120	NA	7	113	NA
ISCED 7	48	NA	18	30	NA
ISCED 6	9	NA	0	9	NA
ISCED 5	0	NA	0	0	NA
ISCED 4 & Below	0	NA	0	0	NA

Table 1.1.10 FTE for researchers by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	445.9	NA	91.7	354.2	NA
ISCED 8	311.3	NA	39.0	272.3	NA
ISCED 7	122.0	NA	50.9	71.1	NA
ISCED 6	11.7	NA	0.9	10.8	NA
ISCED 5	0.9	NA	0.9	0	NA
ISCED 4 & Below	NA	NA	0	0	NA
Total Female	101.7	NA	20.8	80.9	NA
ISCED 8	69.8	NA	6.3	63.5	NA
ISCED 7	29.5	NA	14.5	15.0	NA
ISCED 6	2.4	NA	0.0	2.4	NA
ISCED 5	0.0	NA	0.0	0.0	NA
ISCED 4 & Below	0.0	NA	0.0	0.0	NA

Table 1.1.11 Researchers (HC) by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	808	NA	121	687	NA
Natural Sciences	88	NA	0	88	NA
Engineering & Technology	54	NA	0	54	NA
Medical & Health Sciences	46	NA	0	46	NA
Agricultural & Vet. Sciences	204	NA	77	127	NA
Social Sciences	79	NA	16	63	NA
Humanities & Arts	91	NA	0	91	NA
Not elsewhere classified	246	NA	28	218	NA
Total Female	177	NA	25	152	NA
Natural Sciences	25	NA	0	25	NA
Engineering & Technology	15	NA	0	15	NA
Medical Sciences	17	NA	0	17	NA
Agricultural & Vet. Sciences	54	NA	18	36	NA
Social Sciences	10	NA	2	8	NA
Humanities & Arts	10	NA	0	10	NA
Not elsewhere classified	46	NA	5	41	NA

Table 1.1.12 Full-time equivalent for researchers by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	446.0	NA	91.7	354.3	NA
Natural Sciences	45.2	NA	0	45.2	NA
Engineering & Technology	23.2	NA	0	23.2	NA
Medical Sciences	29.8	NA	0	29.8	NA
Agricultural & Vet. Sciences	146.9	NA	77.0	69.9	NA
Social Sciences	41.9	NA	6.3	35.6	NA
Humanities & Arts	46.3	NA	0.0	46.3	NA
Not elsewhere classified	112.7	NA	8.4	104.3	NA
Total Female	102.4	NA	20.8	81.6	NA
Natural Sciences	13.6	NA	0.0	13.6	NA
Engineering & Technology	6.3	NA	0.0	6.3	NA
Medical Sciences	10.1	NA	0.0	10.1	NA
Agricultural & Vet. Sciences	37.6	NA	18.0	19.6	NA
Social Sciences	8.4	NA	1.3	7.1	NA
Humanities & Arts	6.2	NA	0.0	6.2	NA
Not elsewhere classified	20.2	NA	1.5	18.7	NA

Table 1.1.13 Researchers (HC) by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	808	NA	121	687	NA
Under 25 years	10	NA	NA	10	NA
25-34 Years	166	NA	7	159	NA
35-44 Years	297	NA	36	261	NA
45-54 Years	209	NA	37	172	NA
55-64 Years	108	NA	40	68	NA
65 Years and more	18	NA	1	17	NA
Total Female	177	NA	25	152	NA
Under 25 years	2	NA	0	2	NA
25-34 Years	62	NA	2	60	NA
35-44 Years	70	NA	10	60	NA
45-54 Years	27	NA	5	22	NA
55-64 Years	16	NA	8	8	NA
65 Years and more	0	NA	0	0	NA

Table 1.1.14 FTE for researchers by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Priv. Non-Profit
Total All	445.0	NA	91.7	353.3	NA
Under 25 years	6.3	NA	0.0	6.3	NA
25-34 Years	102.0	NA	7.0	95	NA
35-44 Years	152.4	NA	28.3	124.1	NA
45-54 Years	119.1	NA	30.1	89.0	NA
55-64 Years	56.8	NA	26.0	30.8	NA
65 Years and more	8.4	NA	0.3	8.1	NA
Total Female	102.4	NA	20.8	81.6	NA
Under 25 years	0.0	NA	0.0	1.8	NA
25-34 Years	38.0	NA	2.0	36.0	NA
35-44 Years	37.5	NA	9.1	28.4	NA
45-54 Years	17.5	NA	5.4	12.1	NA
55-64 Years	7.7	NA	4.3	3.4	NA
65 Years and more	0.0	NA	0.0	0.0	NA

1.2 EGYPT 2022

Table 1.2.1 Distribution of R&D personnel (HC) by occupation and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	343 198	104 351	35 984	202 022	841
Researcher	204 179	48 278	23 780	131 753	368
Technician	86 644	37 159	5 326	43 918	241
Support Staff	52 375	18 914	6 878	26 351	232
Female R&D personnel	129 564	15 434	15 782	97 865	483
Researcher	84 915	7 974	10 492	66 245	204
Technician	25 086	3 005	2 195	19 763	123
Support Staff	19 563	4 455	3 095	11 857	156

Table 1.2.2 Full-time equivalent (FTE) for R&D personnel by sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	259 175.3	125 690.1	34 824.5	97 903.9	756.9
Researcher	92 334.8	20 998.7	22 620.5	48 715.6	331.2
Technician	107 385.4	71 316.8	5 326.0	30 742.6	216.9
Support Staff	58 698.2	33 374.5	6 878.0	18 445.7	208.8
Female R&D personnel	122 422.3	59 744.3	15 386.2	46 857.1	434.7
Researcher	38 670.8	3 667.9	10 096.2	24 723.1	183.6
Technician	53 301.4	37 161.6	2 195.0	13 834.1	110.7
Support Staff	30 450.2	18 914.9	3 095.0	8 299.9	140.4

Table 1.2.3 R&D personnel (HC) by level of education and sex

Level of	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	343 198	104 351	35 984	202 022	841
ISCED 8	103 278	4 298	19 082	79 713	185
ISCED 7	34 552	2 520	3 589	28 357	86
ISCED 6	68 158	18 979	10 873	37 736	570
ISCED 5	137 210	78 554	2 440	56 216	NA
ISCED 4 & Below	NA	NA	NA	NA	NA
Female R&D personnel	129 564	15 434	15 782	97 865	483
ISCED 8	44 990	1 151	8 244	35 498	97
ISCED 7	18 442	810	1 658	15 922	52
ISCED 6	31 346	5 041	4 822	21 149	334
ISCED 5	34 786	8 432	1 058	25 296	NA
ISCED 4 & Below	NA	NA	NA	NA	NA

Table 1.2.4 FTE for R&D personnel by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	259 039.0	125 690.1	34 824.5	97 903.9	620.6
ISCED 8	47 985.8	1 882.4	18 157.5	27 899.6	46.3
ISCED 7	15 866.7	1 108.0	3 354.2	11 342.5	62.1
ISCED 6	66 228.8	35 533.4	10 872.0	19 311.2	512.2
ISCED 5	128 957.7	87 166.3	2 440.8	39 350.6	NA
ISCED 4 & Below	NA	NA	NA	NA	NA

Table 1.2.5 R&D personnel by field of R&D and sex (HC)

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	343 198	104 351	35 984	202 022	841
Natural Sciences	55 658	27 830	8 569	19 242	17
Engineering & Technology	65 057	40 341	2 999	21 717	NA
Medical & Health Sciences	92 346	3 019	6 187	82 326	814
Agricultural & Vet. Sciences	37 471	10 062	17 672	9 737	NA
Social Sciences	63 677	23 099	200	40 370	8
Humanities & Arts	28 989	NA	357	28 630	2
Not elsewhere classified	NA	NA	NA	NA	NA
Female R&D personnel	129 564	15 434	15 782	97 865	483
Natural Sciences	16 830	3 449	4 186	9 183	12
Engineering & Technology	13 893	5 489	1 423	6 981	NA
Medical & Health Sciences	45 322	612	2 953	41 286	471
Agricultural & Vet. Sciences	12 491	1 423	6 883	4 185	NA
Social Sciences	26 239	4 461	134	21 644	NA
Humanities & Arts	14 789	NA	203	14 586	NA
Not elsewhere classified	NA	NA	NA	NA	NA

Table 1.2.6 FTE for R&D personnel by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	259 175.3	125 690.1	34 824.5	97 903.9	756.9
Natural Sciences	51 639.1	33 403.5	8 900.0	9 320.6	15.0
Engineering & Technology	62 258.0	48 504.2	3 082.0	10 671.8	NA
Medical & Health Sciences	49 443.4	3 665.5	5 212.5	39 828.4	736.9
Agricultural & Vet. Sciences	33 809.6	12 106.4	17 001.0	4 702.2	NA
Social Sciences	47 737.1	28 010.4	236.0	19 486.7	4.0
Humanities & Arts	14 288.1	NA	393.0	13 894.1	1.0
Not elsewhere classified	NA	NA	NA	NA	NA

Table 1.2.7 Researchers (HC) by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	204 179	48 278	23 780	131 753	368
ISCED 8	103 278	4 298	19 082	79 713	185
ISCED 7	34 552	2 520	3 589	28 357	86
ISCED 6	58 583	33 694	1 109	23 683	97
ISCED 5	7 766	7 766	NA	NA	NA
ISCED 4 & Below	NA	NA	NA	NA	NA
Female Researchers	84 914	7 973	10 492	66 245	204
ISCED 8	44 990	1 151	8 244	35 498	97
ISCED 7	18 441	809	1 658	15 922	52
ISCED 6	19 019	3 549	590	14 825	55
ISCED 5	2 464	2 464	NA	NA	NA
ISCED 4 & Below	NA	NA	NA	NA	NA

Table 1.2.8 FTE for researchers by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	92 666.0	20 998.7	22 620.5	48 715.6	331.2
ISCED 8	48 099.0	1 882.4	18 157.5	27 899.6	159.5
ISCED 7	15 882.7	1 108.0	3 354.2	11 342.5	78.1
ISCED 6	25 271.1	14 595.1	1 108.8	9 473.6	93.6
ISCED 5	3 413.2	3 413.2	NA	NA	NA
ISCED 4 & Below	NA	NA	NA	NA	NA

Table 1.2.9 Researchers (HC) by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	204 179	48 278	23 780	131 753	368
Natural Sciences	31 105	12 876	5 663	12 549	17
Engineering & Technology	34 809	18 664	1 982	14 163	NA
Medical & Health Sciences	59 518	1 397	4 089	53 691	341
Agricultural & Vet. Sciences	22 683	4 655	11 678	6 350	NA
Social Sciences	37 154	10 686	132	26 328	8
Humanities & Arts	18 910	NA	236	18 672	2
Not elsewhere classified	NA	NA	NA	NA	NA
Female Researchers	84 915	7 974	10 492	66 245	204
Natural Sciences	10 426	1 460	2 783	6 171	12
Engineering & Technology	7 134	2 605	946	3 583	NA
Medical & Health Sciences	30 950	396	1 963	28 399	192
Agricultural & Vet. Sciences	7 941	703	4 576	2 662	NA
Social Sciences	18 224	2 810	89	15 325	NA
Humanities & Arts	10 240	NA	135	10 105	NA
Not elsewhere classified	NA	NA	NA	NA	NA

Table 1.2.10 Full-time equivalent for researchers by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	92 666.0	20 998.7	22 620.5	48 715.6	331.2
Natural Sciences	15 896.4	5 580.6	5 663.0	4 637.8	15.0
Engineering & Technology	15 395.6	8 103.5	1 982.0	5 310.2	0.0
Medical & Health Sciences	23 671.1	612.4	2 929.5	19 818.1	311.2
Agricultural & Vet. Sciences	16 040.4	2 022.6	11 678.0	2 339.8	0.0
Social Sciences	14 511.9	4 679.6	132.0	9 696.3	4.0
Humanities & Arts	7 150.5	NA	236.0	6 913.5	1.0
Not elsewhere classified	NA	NA	NA	NA	NA
Female Researchers	38 670.8	3 667.9	10 096.2	24 723.1	183.6
Natural Sciences	5 779.4	671.5	2 783.0	2 314.8	10.10
Engineering & Technology	3 491.0	1 198.3	946.0	1 346.8	NA
Medical & Health Sciences	12 506.6	182.1	1 567.2	10 583.9	173.50
Agricultural & Vet. Sciences	5 899.4	323.6	4 576.0	999.8	NA
Social Sciences	7 075.8	1 292.4	89.0	5 694.4	NA
Humanities & Arts	3 918.6	NA	135.0	3 783.6	NA
Not elsewhere classified	NA	NA	NA	NA	NA

1.3 GHANA 2022

Table 1.3.1 Distribution of R&D personnel by occupation, sector and sex (HC)

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 914	2 267	1 647	NA	NA
Researchers	1 081	494	587	NA	NA
Technicians	1 659	969	690	NA	NA
Support Staff	1 174	804	370	NA	NA
Total Female	1 181	726	455	NA	NA
Researchers	344	177	167	NA	NA
Technicians	456	262	194	NA	NA
Support Staff	381	287	94	NA	NA

Table 1.3.2 FTE for R&D personnel by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 053.8	1 771.7	1 282.1	NA	NA
Researchers	741.1	326.6	414.5	NA	NA
Technicians	1 515.3	837.3	678.0	NA	NA
Support Staff	797.4	607.8	189.6	NA	NA
Total Female	930.2	566.4	363.8	NA	NA
Researchers	239.8	116.2	123.6	NA	NA
Technicians	412.7	221.7	191.0	NA	NA
Support Staff	277.7	228.5	49.2	NA	NA

Table 1.3.3 R&D personnel by level of education, sector and sex (HC)

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 914	2 267	1 647	NA	NA
ISCED 8	335	88	247	NA	NA
ISCED 7	666	284	382	NA	NA
ISCED 6	1 722	1 055	667	NA	NA
ISCED 5	717	492	225	NA	NA
ISCED 4 & Below	474	348	126	NA	NA
Total Female	1 181	726	455	NA	NA
ISCED 8	81	31	50	NA	NA
ISCED 7	207	80	127	NA	NA
ISCED 6	594	399	195	NA	NA
ISCED 5	178	122	56	NA	NA
ISCED 4 & Below	121	94	27	NA	NA

Table 1.3.4 FTE for R&D personnel by level of education, sector and sex (HC)

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 053.8	1 771.7	1 282.1	NA	NA
ISCED 8	254.9	75.3	179.6	NA	NA
ISCED 7	482.7	203.5	279.2	NA	NA
ISCED 6	1 427.0	834.3	592.7	NA	NA
ISCED 5	557.7	392.1	165.6	NA	NA
ISCED 4 & Below	331.5	266.5	65.0	NA	NA

Table 1.3.5 R&D personnel (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 914	2 267	1 647	NA	NA
Natural Sciences	428	100	328	NA	NA
Engineering & Technology	910	689	221	NA	NA
Medical & Health Sciences	742	677	65	NA	NA
Agricultural & Vet. Sciences	639	79	560	NA	NA
Social Sciences	344	161	183	NA	NA
Humanities & Arts	326	149	177	NA	NA
Not elsewhere classified	525	412	113	NA	NA
Total Female	1 181	726	455	NA	NA
Natural Sciences	116	19	97	NA	NA
Engineering & Technology	209	177	32	NA	NA
Medical & Health Sciences	255	232	23	NA	NA
Agricultural & Vet. Sciences	167	35	132	NA	NA
Social Sciences	142	73	69	NA	NA
Humanities & Arts	154	73	81	NA	NA
Not elsewhere classified	138	117	21	NA	NA

Table 1.3.6 FTE for R&D personnel by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 053.9	1 771.8	1 282.1	NA	NA
Natural Sciences	333.9	78.3	255.6	NA	NA
Engineering & Technology	789.4	601.2	188.2	NA	NA
Medical & Health Sciences	643.0	592.0	51.0	NA	NA
Agricultural & Vet. Sciences	488.3	52.3	436.0	NA	NA
Social Sciences	229.1	98.9	130.2	NA	NA
Humanities & Arts	262.2	118.2	144.0	NA	NA
Not elsewhere classified	308.0	230.9	77.1	NA	NA

Table 1.3.7 R&D personnel (HC) by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 914	2 267	1 647	NA	NA
Under 25 years	101	74	27	NA	NA
25-34 Years	1 214	832	382	NA	NA
35-44 Years	1 570	992	578	NA	NA
45-54 Years	779	334	445	NA	NA
55-64 Years	232	32	200	NA	NA
65 Years and more	8	3	5	NA	NA
Unknown	10	0	10	NA	NA
Total Female	1 181	726	455	NA	NA
Under 25 years	28	23	5	NA	NA
25-34 Years	427	310	117	NA	NA
35-44 Years	501	311	190	NA	NA
45-54 Years	178	77	101	NA	NA
55-64 Years	44	2	42	NA	NA
65 Years and more	3	3	0	NA	NA

Table 1.3.8 Researchers (HC) by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	1 081	494	587	NA	NA
ISCED 8	308	78	230	NA	NA
ISCED 7	435	128	307	NA	NA
ISCED 6	245	221	24	NA	NA
ISCED 5	75	59	16	NA	NA
ISCED 4 & Below	18	8	10	NA	NA
Total Female	344	177	167	NA	NA
ISCED 8	75	27	48	NA	NA
ISCED 7	139	33	106	NA	NA
ISCED 6	95	85	10	NA	NA
ISCED 5	34	31	3	NA	NA
ISCED 4 & Below	1	1	0	NA	NA

Table 1.3.9 FTE for researchers by level of education, sector and sex (HC)

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	741.2	326.6	414.6	NA	NA
ISCED 8	231.7	68.6	163.1	NA	NA
ISCED 7	318.1	94.6	223.5	NA	NA
ISCED 6	133.6	116.8	16.8	NA	NA
ISCED 5	50.2	39.0	11.2	NA	NA
ISCED 4 & Below	7.6	7.6	NA	NA	NA

Table 1.3.10 Researchers (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	1 081	494	587	NA	NA
Natural Sciences	180	31	149	NA	NA
Engineering & Technology	217	144	73	NA	NA
Medical & Health Sciences	123	98	25	NA	NA
Agricultural & Vet. Sciences	287	47	240	NA	NA
Social Sciences	111	56	55	NA	NA
Humanities & Arts	96	56	40	NA	NA
Not elsewhere classified	67	62	5	NA	NA
Total Female	344	177	167	NA	NA
Natural Sciences	53	6	47	NA	NA
Engineering & Technology	55	44	11	NA	NA
Medical & Health Sciences	31	21	10	NA	NA
Agricultural & Vet. Sciences	81	19	62	NA	NA
Social Sciences	50	32	18	NA	NA
Humanities & Arts	44	26	18	NA	NA
Not elsewhere classified	30	29	1	NA	NA

Table 1.3.11 FTE for researchers by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	741.1	326.6	414.5	NA	NA
Natural Sciences	128.8	24.4	104.4	NA	NA
Engineering & Technology	168.2	117.0	51.2	NA	NA
Medical & Health Sciences	83.3	65.3	18.0	NA	NA
Agricultural & Vet. Sciences	198.1	28.6	169.5	NA	NA
Social Sciences	64.7	25.9	38.8	NA	NA
Humanities & Arts	60.8	32.8	28.0	NA	NA
Not elsewhere classified	37.2	32.6	4.6	NA	NA
Total Female	239.9	116.3	123.6	NA	NA
Natural Sciences	39.4	4.5	34.9	NA	NA
Engineering & Technology	44.7	36.2	8.5	NA	NA
Medical & Health Sciences	24.5	16.3	8.2	NA	NA
Agricultural & Vet. Sciences	56.4	11.9	44.5	NA	NA
Social Sciences	27.5	14.1	13.4	NA	NA
Humanities & Arts	30.0	16.7	13.3	NA	NA
Not elsewhere classified	17.4	16.6	0.8	NA	NA

Table 1.3.12 Researchers (HC) by age and sector

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	1 081	494	587	NA	NA
Under 25 years	32	25	7	NA	NA
25-34 Years	232	160	72	NA	NA
35-44 Years	496	235	261	NA	NA
45-54 Years	238	57	181	NA	NA
55-64 Years	74	13	61	NA	NA
65 Years and more	9	4	5	NA	NA
Total Female	344	177	167	NA	NA
Under 25 years	13	10	3	NA	NA
25-34 Years	82	65	17	NA	NA
35-44 Years	183	90	93	NA	NA
45-54 Years	49	7	42	NA	NA
55-64 Years	14	2	12	NA	NA
65 Years and more	3	3	0	NA	NA

Table 1.3.13 FTE for researchers by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	686.4	293.9	392.5	NA	NA
Under 25 years	14.9	10.0	4.9	NA	NA
25-34 Years	144.9	95.4	49.5	NA	NA
35-44 Years	317.6	143.7	173.9	NA	NA
45-54 Years	158.8	35.7	123.1	NA	NA
55-64 Years	45.1	7.1	38.0	NA	NA
65 Years and more	5.1	2.0	3.1	NA	NA
Total Female	225.1	101.5	123.6	NA	NA
Under 25 years	6.1	4.0	2.1	NA	NA
25-34 Years	45.9	34.0	11.9	NA	NA
35-44 Years	125.2	57.0	68.2	NA	NA
45-54 Years	33.2	2.0	31.2	NA	NA
55-64 Years	14.7	4.5	10.2	NA	NA
65 Years and more	0.0	0.0	0.0	NA	NA

1.4 MALAWI 2019

Table 1.4.1 Distribution of R&D personnel (HC) by occupation and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	2 829	58	1 176	1 443	152
Researchers	1256	41	187	1006	22
Technicians	599	1	287	214	97
Support Staff	974	16	702	223	33
Female R&D personnel	862	12	297	486	67
Researchers	393	6	45	334	8
Technicians	208	NA	97	64	47
Support Staff	261	6	155	88	12

Table 1.4.2 Full-time equivalent (FTE) for R&D personnel by sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	1 655.70	16.5	1 090.20	495.9	53.1
Researchers	472.5	11	161.7	284.3	15.5
Technicians	414.5	0.5	271.4	115.1	27.5
Support Staff	768.9	5	657.1	96.6	10.2
Female R&D personnel	468.1	5	275.8	165.1	22.2
Researchers	145.7	2.7	43.4	94.5	5.1
Technicians	142	0	92.2	37	12.8
Support Staff	180.4	2.3	140.2	33.6	4.3

Table 1.4.3 R&D personnel Headcount by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	2 829	58	1 176	1 443	152
ISCED 8	278	5	42	225	6
ISCED 7	704	10	96	586	12
ISCED 6	587	17	170	318	82
ISCED 5	380	20	118	208	34
ISCED 4 & Below	880	6	750	106	18
Female R&D personnel	862	12	297	486	67
ISCED 8	71	NA	10	60	1
ISCED 7	238	2	25	207	4
ISCED 6	233	5	64	120	44
ISCED 5	121	4	40	64	13
ISCED 4 & Below	199	1	158	35	5

Table 1.4.4 FTE for R&D personnel (HC) by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	1 656.10	16.5	1 090.20	495.9	53.6
ISCED 8	106.5	1.7	32.9	67.9	4
ISCED 7	279.6	4.2	83.8	180.7	11
ISCED 6	281	5.9	152.3	97	25.8
ISCED 5	222.4	2.8	104.6	102.2	12.8
ISCED 4 & Below	766.7	2	716.6	48.1	NA

Table 1.4.5 R&D personnel (HC) by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	2 829	58	1 176	1 443	152
Natural Sciences	244	3	107	134	0
Engineering & Technology	283	6	24	250	3
Medical & Health Sciences	541	11	6	523	1
Agricultural & Vet. Sciences	546	14	472	26	34
Social Sciences	385	11	42	271	61
Humanities & Arts	94	4	11	77	2
Not elsewhere classified	736	9	514	162	51
Female R&D personnel	862	12	297	486	67
Natural Sciences	53	0	23	30	0
Engineering & Technology	44	0	5	39	0
Medical & Health Sciences	226	3	0	222	1
Agricultural & Vet. Sciences	161	3	133	12	13
Social Sciences	141	2	19	85	35
Humanities & Arts	35	2	9	22	2
Not elsewhere classified	202	2	108	76	16

Table 1.4.6 FTE for R&D personnel by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	1 655.70	16.5	1 090.20	495.9	53.1
Natural Sciences	127.6	0.3	80.9	46.4	0
Engineering & Technology	102.4	1.7	16.5	81.2	3
Medical & Health Sciences	198.6	3.3	5.6	189.7	0
Agricultural & Vet. Sciences	475.5	0	457	2.6	15.9
Social Sciences	155.2	4.4	30.2	100.8	19.8
Humanities & Arts	27.7	2.5	9.1	14.1	2
Not elsewhere classified	568.7	4.3	490.9	61.1	12.4

Table 1.4.7 Researchers (HC) by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	1 256	41	187	1 006	22
ISCED 8	273	5	41	221	6
ISCED 7	640	10	84	538	8
ISCED 6	240	15	44	173	8
ISCED 5	88	7	8	73	0
ISCED 4 & Below	15	4	10	1	0
Female Researchers	393	6	45	334	8
ISCED 8	70	0	10	59	1
ISCED 7	217	2	22	190	3
ISCED 6	82	4	9	65	4
ISCED 5	21	0	1	20	0
ISCED 4 & Below	3	0	3	0	0

Table 1.4.8 FTE for researchers by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	622.4	11	311.7	284.3	15.5
ISCED 8	105.6	1.7	32.6	67.3	4
ISCED 7	239.4	4.2	73.9	157	4.4
ISCED 6	86.6	3.9	35.6	40	7.1
ISCED 5	28.9	1.2	8	19.7	NA
ISCED 4 & Below	161.9	NA	161.7	0.2	NA
Not classified	NA	NA	NA	NA	NA

Table 1.4.9 Researchers (HC) by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	1 256	41	187	1 006	22
Natural Sciences	159	3	51	105	0
Engineering & Technology	201	5	13	183	0
Medical & Health Sciences	288	11	6	271	0
Agricultural & Vet. Sciences	130	4	101	20	5
Social Sciences	296	11	10	258	17
Humanities & Arts	63	3	3	57	0
Not elsewhere classified	119	4	3	112	
Female Researchers	393	6	45	334	8
Natural Sciences	31	0	8	23	0
Engineering & Technology	27	0	1	26	0
Medical & Health Sciences	134	3	0	131	0
Agricultural & Vet. Sciences	40	0	28	11	1
Social Sciences	91	2	2	80	7
Humanities & Arts	18	1	3	14	0
Not elsewhere classified	52	0	3	49	0

Table 1.4.10 Full-time equivalent for researchers by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	472.5	11	161.7	284.3	15.5
Natural Sciences	75.3	0.3	37.5	37.5	0
Engineering & Technology	53.1	1.5	7.6	44	0
Medical & Health Sciences	70.6	3.3	1.6	65.7	0
Agricultural & Vet. Sciences	105.6	0	98	2.6	5
Social Sciences	114.5	4.4	8	93	9.1
Humanities & Arts	8.4	1.5	2.6	4.3	0
Not elsewhere classified	45	0	6.4	37.2	1.4
Female Researchers	145.6	2.7	43.4	94.5	5
Natural Sciences	12.2	0	5.2	7	0
Engineering & Technology	6.4	0	0.6	5.8	0
Medical & Health Sciences	35.4	0.9	0	34.5	0
Agricultural & Vet. Sciences	28.4	0	27	0.4	1
Social Sciences	37	1.3	1.6	31.1	3
Humanities & Arts	4.6	0.5	2.6	1.5	0
Not elsewhere classified	21.6	0	6.4	14.2	1

1.5 MALI 2021

Table 1.5.1 Distribution of R&D personnel (HC) by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	2 009	72	1 215	567	155
Researchers	776	30	348	368	30
Technicians	752	36	496	159	61
Support Staff	481	6	371	40	64
Female R&D personnel	394	2	279	71	42
Researchers	92	0	54	34	4
Technicians	182	2	131	27	22
Support Staff	120	0	94	10	16

Table 1.5.2 Full-time equivalent (FTE) for R&D personnel by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	1 645.70	27	1 006.60	458.6	153.5
Researchers	632.1	12.6	299	290.5	30
Technicians	603.9	9.2	407.1	128.1	59.5
Support Staff	410.5	6	300.5	40	64
Female R&D personnel	322.6	0	228	58.6	36
Researchers	79.3	0	47	28.3	4
Technicians	145.7	0	103.4	20.3	22
Support Staff	97.6	0	77.6	10	10

Table 1.5.3 R&D personnel (HC) by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	2 009	72	1 215	567	155
ISCED 8	348	0	145	182	21
ISCED 7	689	54	311	263	61
ISCED 6	369	18	251	65	35
ISCED 5	338	0	290	40	8
ISCED 4 & Below	265	0	218	17	30
Female R&D personnel	394	2	279	71	42
ISCED 8	47	0	30	13	4
ISCED 7	134	0	69	43	22
ISCED 6	95	2	72	10	11
ISCED 5	73	0	67	4	2
ISCED 4 & Below	45	0	41	1	3

Table 1.5.4 FTE for R&D personnel by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	1 646.30	27.7	1 006.60	458.5	153.5
ISCED 8	283.7	NA	122.1	142.6	19
ISCED 7	595.6	18.5	310.3	210.8	56
ISCED 6	312.8	9.2	206.6	60	37
ISCED 5	299.8	NA	248.3	40	11.5
ISCED 4 & Below	154.4	NA	119.3	5.1	30

Table 1.5.5 R&D personnel (HC) by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	2 009	72	1 215	567	155
Natural Sciences	149	21	75	44	9
Engineering & Technology	177	NA	73	104	0
Medical & Health Sciences	37	NA	30	0	7
Agricultural & Vet. Sciences	976	NA	955	0	21
Social Sciences	344	47	46	236	15
Humanities & Arts	186		20	166	0
Not elsewhere classified	140	4	16	17	103
Female R&D personnel	394	2	279	71	42
Natural Sciences	35	0	19	14	2
Engineering & Technology	17	2	8	7	0
Medical & Health Sciences	20	0	17	0	3
Agricultural & Vet. Sciences	207	0	205	0	2
Social Sciences	48	0	16	27	5
Humanities & Arts	28	0	6	22	0
Not elsewhere classified	39	0	8	1	30

Table 1.5.6 FTE for R&D personnel by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	1646.60	27.8	1 006.80	458.5	153.5
Natural Sciences	64	NA	25	30	9
Engineering & Technology	91.2	4.8	36.3	50.1	NA
Medical & Health Sciences	36.8	4.8	28	NA	4
Agricultural & Vet. Sciences	862.3	NA	839.8	NA	22.5
Social Sciences	280.9	15.7	42.9	207.3	15
Humanities & Arts	187.4	2.6	18.8	166	NA
Not elsewhere classified	124.1	NA	16	5.1	103

Table 1.5.7 R&D personnel (HC) by age and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	2 009	72	1 215	567	155
Under 25 years	1	0	1	0	0
25-34 Years	309	20	203	59	27
35-44 Years	499	32	247	158	62
45-54 Years	787	13	508	215	51
55-64 Years	377	7	225	132	13
65 Years and more	36	0	31	3	2
Female R&D personnel	394	2	279	71	42
Under 25 years	1	0	1	0	0
25-34 Years	77	1	60	11	5
35-44 Years	185	1	140	20	24
45-54 Years	107	0	64	30	13
55-64 Years	22	0	12	10	0
65 Years and more	2	0	2	0	0

Table 1.5.8 Researchers (HC) by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	776	30	348	368	30
ISCED 8	328	0	126	182	20
ISCED 7	419	30	197	186	6
ISCED 6	8	0	4	0	4
ISCED 5	21	0	21	0	0
ISCED 4 & Below	0	0	0	0	0
Female Researchers	92	0	54	34	4
ISCED 8	29	0	14	12	3
ISCED 7	61	0	39	22	0
ISCED 6	2	0	1	0	1
ISCED 5	0	0	0	0	0
ISCED 4 & Below	0	0	0	0	0

Table 1.5.9 FTE for researchers by level of education and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	632.1	12.6	299	290.5	30
ISCED 8	247.7	NA	100.6	142.6	4.5
ISCED 7	364.3	12.6	187.3	147.9	16.5
ISCED 6	10	NA	4	NA	6
ISCED 5	8.1	NA	7.1	NA	1
ISCED 4 & Below	2	NA	NA	NA	2

Table 1.5.10 Researchers (HC) by field of R&D anxd sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	746	0	348	368	30
Natural Sciences	45	0	44	0	1
Engineering & Technology	131	0	27	104	0
Medical & Health Sciences	9	0	5	0	4
Agricultural & Vet. Sciences	246	0	243	0	3
Social Sciences	188	0	15	165	8
Humanities & Arts	106	0	7	99	0
Not elsewhere classified	21	0	7	0	14
Female Researchers	92	0	54	34	4
Natural Sciences	14	0	14	0	0
Engineering & Technology	11	0	4	7	0
Medical & Health Sciences	7	0	6	0	1
Agricultural & Vet. Sciences	23	0	23	0	0
Social Sciences	15	0	2	12	1
Humanities & Arts	18	0	3	15	0
Not elsewhere classified	4	0	2	0	2

Table 1.5.11 Full-time equivalent (FTE) for researchers by field of R&D and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	632.1	12.6	299	290.5	30
Natural Sciences	36.1	0	35.1	0	1
Engineering & Technology	66.9	6	10.8	50.1	0
Medical & Health Sciences	12	3	5	0	4
Agricultural & Vet. Sciences	218.7	2	213.7	0	3
Social Sciences	172.8	0	23.4	141.4	8
Humanities & Arts	111.6	1.6	11	99	0
Not elsewhere classified	14	0	0	0	14
Female Researchers	79.3	0	47	28.3	4
Natural Sciences	8	0	8	0	0
Engineering & Technology	3.3	0	0	3.3	0
Medical & Health Sciences	2	0	1	0	1
Agricultural & Vet. Sciences	33	0	33	0	0
Social Sciences	13	0	2	10	1
Humanities & Arts	18	0	3	15	0
Not elsewhere classified	2	0	0	0	2

Table 1.5.12 Researchers Headcount by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	776	30	348	368	30
Under 25 years	0	0	0	0	0
25-34 Years	19	7	8	1	3
35-44 Years	146	11	57	66	12
45-54 Years	401	4	219	166	12
55-64 Years	195	8	54	132	1
65 Years and more	15	0	10	3	2

1.6 MAURITIUS 2023

Table 1.6.1 Distribution of R&D personnel (HC) by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	3 008	140	1 267	1 555	46
Researchers	1 578	40	525	998	15
Technicians	554	68	290	170	26
Support Staff	876	32	452	387	5
Female R&D personnel	1 456	55	488	887	26
Researchers	771	12	253	498	8
Technicians	257	29	136	77	15
Support Staff	428	14	99	312	3

Table 1.6.2 Full-time equivalent (FTE) for R&D personnel by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	1 676.70	67	894.9	678.6	36.2
Researchers	739.2	29.9	262.3	438.3	8.7
Technicians	284.5	26.4	215.5	20.1	22.5
Support Staff	653	10.7	417.1	220.2	5
Female R&D personnel	764.5	22.1	313.2	406.7	22.5
Researchers	354.8	9	125.3	214.5	6
Technicians	133.4	9.4	101.9	8.5	13.6
Support Staff	276.3	3.7	86	183.6	3

Table 1.6.3 R&D personnel (HC) by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	3 008	140	1 267	1 555	46
ISCED 8	477	12	76	381	8
ISCED 7	849	63	385	372	29
ISCED 6	870	51	263	547	9
ISCED 5	208	10	25	173	NA
ISCED 4 & Below	604	4	518	82	NA
Female R&D personnel	1 456	55	488	887	26
ISCED 8	224	6	30	185	3
ISCED 7	424	24	191	191	18
ISCED 6	510	19	152	334	5
ISCED 5	135	5	7	123	NA
ISCED 4 & Below	163	1	108	54	NA

Table 1.6.4 FTE for R&D personnel by level of education and sector

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	1 676.70	67	894.9	678.6	36.2
ISCED 8	223.9	10	55.5	155.1	3.3
ISCED 7	387.8	26.5	212.9	122.4	26
ISCED 6	488.9	27.7	161.5	292.8	6.9
ISCED 5	98.7	0.5	21.8	76.4	NA
ISCED 4 & Below	477.5	2.4	443.2	32	NA

Table 1.6.5 R&D personnel (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	3 008	140	1 267	1 555	46
Natural Sciences	514	26	142	311	35
Engineering & Technology	452	26	107	316	3
Medical & Health Sciences	208	15	114	79	0
Agricultural & Vet. Sciences	547	8	487	52	0
Social Sciences	475	4	93	372	6
Humanities & Arts	405	61	208	134	2
Not elsewhere classified	407	0	116	291	0
Female R&D personnel	1 456	55	488	887	26
Natural Sciences	247	11	65	150	21
Engineering & Technology	163	5	36	121	1
Medical & Health Sciences	124	8	59	57	0
Agricultural & Vet. Sciences	168	0	135	33	0
Social Sciences	275	0	60	213	2
Humanities & Arts	234	31	110	91	2
Not elsewhere classified	245	0	23	222	0

Table 1.6.6 FTE for R&D personnel by area of R&D

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	1 676.70	67	894.9	678.6	36.2
Natural Sciences	281.9	21.8	92.7	135.5	32
Engineering & Technology	185.8	18.2	31.6	135.3	0.7
Medical & Health Sciences	161.3	15	114	32.3	0
Agricultural & Vet. Sciences	452.4	5.8	426.6	18.5	1.5
Social Sciences	241.5	1.1	98.1	140.4	2
Humanities & Arts	92.5	5.3	30.8	56.4	0
Not elsewhere classified	261.3	0	101.1	160.3	0

Table 1.6.7 R&D personnel (HC) by age and sector

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total R&D personnel	3 008	140	1 267	1 555	46
Under 25 years	65	10	13	42	0
25-34 Years	644	40	260	306	38
35-44 Years	990	86	344	554	6
45-54 Years	796	4	387	404	1
55-64 Years	392	0	187	204	1
65 Years and more	11	0	2	9	0
Unknown	110	NA	74	36	NA
Female R&D personnel	1 456	55	488	887	26
Under 25 years	46	3	5	15	23
25-34 Years	366	13	157	194	2
35-44 Years	556	39	165	351	1
45-54 Years	317	0	113	204	0
55-64 Years	142	0	46	96	0
65 Years and more	3	0	0	3	0
Unknown	26	NA	2	24	NA

Table 1.6.8 Researchers by qualification, sector and sex (HC)

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	1 578	40	525	998	15
ISCED 8	447	8	56	375	8
ISCED 7	572	19	280	266	7
ISCED 6	467	12	119	336	NA
ISCED 5	32	NA	11	21	NA
ISCED 4 & Below	60	1	59	NA	NA
Female Researchers	771	12	253	498	8
ISCED 8	210	4	20	183	3
ISCED 7	267	5	132	125	5
ISCED 6	259	3	68	188	NA
ISCED 5	5	NA	3	2	NA
ISCED 4 & Below	30	NA	30	NA	NA

Table 1.6.9 FTE for researchers by qualification, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	739.2	29.9	262.3	438.3	8.69
ISCED 8	211	6	50.1	151.6	3.3
ISCED 7	247.2	13.2	145.8	82.9	5.4
ISCED 6	246.4	9.8	49.5	187.1	NA
ISCED 5	27.8	NA	11	16.8	NA
ISCED 4 & Below	6.9	1	5.9	NA	NA

Table 1.6.10 Researchers (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	1 578	40	525	998	15
Natural Sciences	281	14	75	182	10
Engineering & Technology	318	15	63	238	2
Medical & Health Sciences	67	6	9	52	0
Agricultural & Vet. Sciences	155	3	131	21	0
Social Sciences	398	1	44	351	2
Humanities & Arts	316	1	202	112	1
Not elsewhere classified	43	0	1	42	0
Female Researchers	771	12	253	498	8
Natural Sciences	120	6	34	74	6
Engineering & Technology	107	2	21	83	1
Medical & Health Sciences	38	3	2	33	0
Agricultural & Vet. Sciences	79	0	66	13	0
Social Sciences	220	0	24	196	0
Humanities & Arts	181	1	105	74	1
Not elsewhere classified	26	0	1	25	0

Table 1.6.11 FTE for researchers by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	739.2	29.9	262.3	438.3	8.7
Natural Sciences	170.5	10.5	55.5	97.5	7
Engineering & Technology	140.4	11.6	20.8	107.6	0.4
Medical & Health Sciences	39.7	6	9	24.7	0
Agricultural & Vet. Sciences	94.7	1.5	82.7	10.5	0
Social Sciences	201.4	0.2	68	132.9	0.3
Humanities & Arts	70.1	0.3	25.3	43.5	1
Not elsewhere classified	22.7	0	1	21.7	0
Female Researchers	354.8	9	125.3	214.5	6
Natural Sciences	73.1	4.5	25.7	38.1	4.8
Engineering & Technology	52.1	1.3	8.3	42.3	0.2
Medical & Health Sciences	22.1	3	2	17.1	0
Agricultural & Vet. Sciences	30	0	23.1	6.9	0
Social Sciences	110	0	52.9	57.1	0
Humanities & Arts	43.2	0.3	12.3	29.6	1
Not elsewhere classified	14.5	0	1	13.5	0

Table 1.6.12 Researchers (HC) by age and sector

Age of Researchers	Total	Business	Government	Higher Educ.	Private Non-Profit
Total Researchers	1 578	40	525	998	15
Under 25 years	44	1	7	36	0
25-34 Years	375	22	112	230	11
35-44 Years	527	15	160	349	3
45-54 Years	387	1	154	232	0
55-64 Years	195	1	82	111	1
65 Years and more	11	0	2	9	0
Not Classified	39	NA	8	31	NA

1.7 NAMIBIA 2022

Table 1.7.1 Distribution of R&D personnel (HC) by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 439	104	659	2 576	100
Researchers	2 502	60	595	1 800	47
Technicians	275	19	43	192	21
Support Staff	662	25	21	584	32
Total Female	1 784	40	380	1 319	45
Researchers	1 238	27	340	846	25
Technicians	142	8	26	100	8
Support Staff	404	5	14	373	12

Table 1.7.2 Full-time equivalent for R&D personnel by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	887.2	66.2	78.2	677.2	65.6
Researchers	641	43.9	50.9	504.2	42
Technicians	91	7.9	15.6	56.2	11.3
Support Staff	155.2	14.4	11.7	116.8	12.3
Total Female	446.6	29.4	48.1	335.5	33.6
Researchers	304.5	22.7	28.9	231.5	21.4
Technicians	48.3	3.5	11.4	29.4	4
Support Staff	93.8	3.2	7.8	74.6	8.2

Table 1.7.3 R&D personnel (HC) by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	3 439	104	659	2 576	100
ISCED 8	584	4	11	556	13
ISCED 7	1177	30	127	996	24
ISCED 6	880	43	173	635	29
ISCED 5	313	10	122	172	9
ISCED 4 & Below	485	17	226	217	25
Total Female	1 784	40	380	1 319	45
ISCED 8	224	1	6	208	9
ISCED 7	616	9	75	520	12
ISCED 6	493	25	96	357	15
ISCED 5	203	1	89	106	7
ISCED 4 & Below	248	4	114	128	2

Table 1.7.4 FTE for R&D personnel by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	887.2	66.2	78.2	677.2	65.6
ISCED 8	174.1	2.4	2.9	157	11.8
ISCED 7	333.5	23.2	32.8	257.5	20
ISCED 6	246.6	27.9	27.1	171.9	19.7
ISCED 5	55.8	6.9	3.5	38.9	6.5
ISCED 4 & Below	77.2	5.8	11.9	51.9	7.6
Total Female	446.6	29.4	48.1	335.5	33.6
ISCED 8	67.7	1	2	56.9	7.8
ISCED 7	174	9	22.3	132.3	10.4
ISCED 6	133.4	17.1	13.9	92.2	10.2
ISCED 5	32.2	1	2.8	23.4	5
ISCED 4 & Below	39.3	1.3	7.1	30.7	0.2

Table 1.7.5 R&D personnel (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 439	104	659	2 576	100
Natural Sciences	526	20	113	350	43
Engineering & Technology	246	39	4	203	NA
Medical and Health Sciences	390	9	10	370	1
Agricultural & Vet. Sciences	234	14	NA	204	16
Social Sciences	809	10	19	775	5
Humanities & Arts	68	2	3	61	2
Crosscutting/Multidisciplinary	1 068	10	510	515	33
Not elsewhere classified	98	NA	NA	98	NA
Total Female	1 784	40	380	1 319	45
Natural Sciences	250	5	59	164	22
Engineering & Technology	81	14	4	63	NA
Medical and Health Sciences	227	4	7	215	1
Agricultural & Vet. Sciences	99	5	NA	86	8
Social Sciences	420	6	15	395	4
Humanities & Arts	34	NA	1	31	2
Not elsewhere classified	673	6	294	365	8

Table 1.7.6 R&D personnel (HC) by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 439	104	659	2 576	100
Under 25 years	66	3	2	47	14
25-34 Years	676	56	58	518	44
35-44 Years	1 100	26	67	989	18
45-54 Years	683	16	23	625	19
55-64 Years	362	2	5	354	1
65 Years and more	48	1	NA	43	4
Not Specified	504	NA	504	NA	NA
Total Female	1 784	40	380	1 319	45
Under 25 years	39	3	2	26	8
25-34 Years	404	27	38	316	23
35-44 Years	544	6	33	499	6
45-54 Years	322	3	11	302	6
55-64 Years	161	1	3	156	1
65 Years and more	314	NA	293	20	1

Table 1.7.7 Researchers (HC) by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	2 502	60	595	1 800	47
ISCED 8	562	4	11	535	12
ISCED 7	1 031	25	119	868	19
ISCED 6	488	25	148	305	10
ISCED 5	142	6	110	23	3
ISCED 4 & Below	279	0	207	69	3
Total Female	1 238	27	340	846	25
ISCED 8	216	1	6	201	8
ISCED 7	529	8	69	442	10
ISCED 6	249	17	78	149	5
ISCED 5	103	1	83	17	2
ISCED 4 & Below	141	0	104	37	0

Table 1.7.8 FTE for researchers by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	640.6	43.9	50.5	504.2	42
ISCED 8	169.4	2.4	2.9	152.8	11.3
ISCED 7	292.9	18.9	28.6	228.9	16.5
ISCED 6	139.5	17.8	19	94	8.7
ISCED 5	14.8	4.8	0	7.5	2.5
ISCED 4 & Below	24	0	0	21	3
Total Female	304.5	22.7	28.9	231.5	21.4
ISCED 8	65.8	1	2	55.5	7.3
ISCED 7	150.2	8	18.2	115.1	8.9
ISCED 6	69.5	12.7	8.7	44.4	3.7
ISCED 5	7.6	1	0	5.1	1.5
ISCED 4 & Below	11.4	0	0	11.4	0

Table 1.7.9 Researchers (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	2 502	60	595	1 800	47
Natural Sciences	379	7	75	269	28
Engineering & Technology	187	19	3	165	0
Medical and Health Sciences	315	9	6	299	1
Agricultural & Vet. Sciences	178	7	0	165	6
Social Sciences	680	10	10	656	4
Humanities & Arts	61	0	3	58	0
Multi-Disciplinary (Classified Elsewhere)	109	8	3	90	8
Not elsewhere	593	0	495	98	0
Female	1 238	27	340	846	25
Natural Sciences	171	2	34	120	15
Engineering & Technology	56	7	3	46	0
Medical & Health Sciences	180	4	5	170	1
Agricultural & Vet. Sciences	72	4	0	65	3
Social Sciences	329	6	7	313	3
Humanities & Arts	30	0	1	29	0
Multi-disciplinary (Classified Elsewhere)	66	0	1	58	3
Not elsewhere classified	338	4	289	45	0

Table 1.7.10 Researchers (HC) by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	2 502	60	595	1 800	47
Under 25 years	45	3	NA	39	3
25-34 Years	396	31	36	305	24
35-44 Years	751	13	50	683	5
45-54 Years	476	10	12	444	10
55-64 Years	292	2	2	287	1
65 Years and more	47	1	NA	42	4
Not Classified	495	NA	495	NA	NA
Total Female	1 238	27	51	846	25
Under 25 years	24	3	NA	19	2
25-34 Years	234	16	19	185	14
35-44 Years	340	4	25	309	2
45-54 Years	204	3	6	190	5
55-64 Years	126	1	1	123	1
65 Years and more	21	NA	NA	20	1
Not Classified	289	NA	289	NA	NA

1.8 NIGERIA 2019

Table 1.8.1 Distribution of R&D personnel (HC) by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	41 431	NA	16 470	24 961	NA
Researchers	20 881	NA	6 215	14 666	NA
Technicians	11 179	NA	5 495	5 684	NA
Support Staff	9 371	NA	4 760	4 611	NA
Total Female	13 002	NA	5 753	7 249	NA
Researchers	6 393	NA	2 150	4 243	NA
Technicians	2 684	NA	1 517	1 167	NA
Support Staff	3 925	NA	2 086	1 839	NA

Table 1.8.2 FTE for R&D personnel by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	6 260.70	NA	3 779.30	2 481.40	NA
Researchers	4 583.90	NA	2 237.40	2 346.50	NA
Technicians	808.7	NA	780.3	28.4	NA
Support Staff	868.1	NA	761.6	106.5	NA
Total Female	2 050.00	NA	1 323.20	726.8	NA
Researchers	1 452.90	NA	774	678.9	NA
Technicians	221	NA	215.4	5.6	NA
Support Staff	376.1	NA	333.8	42.3	NA

Table 1.8.3 R&D personnel (HC) by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	41 431	NA	16 470	24 961	NA
ISCED 8	8 279	NA	1 212	7 067	NA
ISCED 7	8 707	NA	2 036	6 671	NA
ISCED 6	9 316	NA	4 537	4 779	NA
ISCED 5	8 638	NA	3 959	4 679	NA
ISCED 4 & Below	6 491	NA	4 726	1 765	NA
Total Female	13 002	NA	5 753	7 249	NA
ISCED 8	2 374	NA	296	2 078	NA
ISCED 7	2 868	NA	717	2 151	NA
ISCED 6	3 375	NA	1 755	1 620	NA
ISCED 5	2 331	NA	1 481	850	NA
ISCED 4 & Below	2 054	NA	1 504	550	NA

Table 1.8.4 FTE for R&D personnel by level of education and sector

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	6 260.70	NA	3 779.30	2 481.40	NA
ISCED 8	710.3	NA	267.4	442.9	NA
ISCED 7	867.3	NA	449.3	418	NA
ISCED 6	1 300.70	NA	1 001.20	299.5	NA
ISCED 5	1 166.80	NA	873.6	293.2	NA
ISCED 4 & Below	2 215.60	NA	1 187.80	1 027.80	NA

Table 1.8.5 R&D personnel (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	41 431	NA	15 845	25 586	NA
Natural Sciences	5 709	NA	1 647	4 062	NA
Engineering & Technology	4 192	NA	2 097	2 095	NA
Medical & Health Sciences	5 034	NA	1 792	3 242	NA
Agricultural & Vet. Sciences	6 596	NA	3 816	2 780	NA
Social Sciences	5 440	NA	1 427	4 013	NA
Humanities & Arts	3 005	NA	904	2 101	NA
Not elsewhere classified	11 455	NA	4 162	7 293	NA
Total Female	13 002	NA	4 998	8 004	NA
Natural Sciences	1 883	NA	739	1 144	NA
Engineering & Technology	817	NA	384	433	NA
Medical & Health Sciences	1 644	NA	460	1 184	NA
Agricultural & Vet. Sciences	1 957	NA	1 243	714	NA
Social Sciences	1 840	NA	606	1 234	NA
Humanities & Arts	1 034	NA	360	674	NA
Not elsewhere classified	3 827	NA	1 206	2 621	NA

Table 1.8.6 FTE for R&D personnel (HC) by field of R&D and sector

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	6 260.70	NA	4 271.40	1 989.30	NA
Natural Sciences	618	NA	363.4	254.6	NA
Engineering & Technology	594	NA	462.7	131.3	NA
Medical & Health Sciences	598.6	NA	395.4	203.2	NA
Agricultural & Vet. Sciences	1 016.30	NA	842.1	174.2	NA
Social Sciences	566.4	NA	314.9	251.5	NA
Humanities & Arts	331.1	NA	199.5	131.7	NA
Not elsewhere classified	2 536.30	NA	1 693.40	842.9	NA

Table 1.8.7 R&D personnel (HC) by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	41 431	NA	16 309	25 122	NA
Under 25 years	4 879	NA	2 701	2 178	NA
25-34 Years	5 909	NA	2 685	3 224	NA
35-44 Years	11 910	NA	4 755	7 155	NA
45-54 Years	10 094	NA	3 522	6 572	NA
55-64 Years	4 767	NA	1 266	3 501	NA
65 Years and more	3 872	NA	1 380	2 492	NA
Total Female	13 002	NA	4 409	8 593	NA
Under 25 years	1 130	NA	455	675	NA
25-34 Years	2 122	NA	881	1 241	NA
35-44 Years	4 179	NA	1 476	2 703	NA
45-54 Years	3 332	NA	1 159	2 173	NA
55-64 Years	1 178	NA	345	833	NA
65 Years and more	1 061	NA	93	968	NA

Table 1.8.8 Researchers (HC) by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	20 881	NA	6 215	14 666	NA
ISCED 8	8 067	NA	1 141	6 926	NA
ISCED 7	6 752	NA	1 281	5 471	NA
ISCED 6	4 024	NA	2 038	1 986	NA
ISCED 5	887	NA	624	263	NA
ISCED 4 & Below	1 151	NA	1 131	20	NA
Total Female	6 393	NA	2 150	4 243	NA
ISCED 8	2 298	NA	267	2 031	NA
ISCED 7	2 096	NA	416	1 680	NA
ISCED 6	1 080	NA	623	457	NA
ISCED 5	300	NA	227	73	NA
ISCED 4 & Below	619	NA	617	2	NA

Table 1.8.9 FTE for researchers by level of education and sector

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	4 583.90	NA	2 522.30	2 061.60	NA
ISCED 8	1 591.50	NA	674.2	917.3	NA
ISCED 7	1 125.10	NA	549.7	575.4	NA
ISCED 6	985.6	NA	647.2	338.4	NA
ISCED 5	423.8	NA	283.5	140.3	NA
ISCED 4 & Below	458.9	NA	368.8	90.2	NA

Table 1.8.10 Researchers (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	20 881	NA	4 381	16 500	NA
Natural Sciences	3 706	NA	992	2 714	NA
Engineering & Technology	2 396	NA	992	1 404	NA
Medical & Health Sciences	3 150	NA	1 046	2 104	NA
Agricultural & Vet. Sciences	2 629	NA	931	1 698	NA
Social Sciences	3 104	NA	142	2 962	NA
Humanities & Arts	1 630	NA	102	1 528	NA
Not elsewhere classified	4 266	NA	176	4 090	NA
Total Female	6 393	NA	1 352	5 041	NA
Natural Sciences	1 138	NA	427	711	NA
Engineering & Technology	501	NA	236	265	NA
Medical & Health Sciences	974	NA	234	740	NA
Agricultural & Vet. Sciences	710	NA	323	387	NA
Social Sciences	881	NA	40	841	NA
Humanities & Arts	450	NA	23	427	NA
Not elsewhere classified	1 739	NA	69	1 670	NA

Table 1.8.11 FTE for researchers by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	4 583.90	NA	1 683.80	2 900.10	NA
Natural Sciences	791.4	NA	357.1	434.2	NA
Engineering & Technology	581.8	NA	357.1	224.6	NA
Medical & Health Sciences	713.2	NA	376.6	336.6	NA
Agricultural & Vet. Sciences	606.8	NA	335.2	271.7	NA
Social Sciences	525	NA	51.1	473.9	NA
Humanities & Arts	281.2	NA	36.7	244.5	NA
Not elsewhere classified	1084.5	NA	170	914.5	NA
Total Female	1 453.90	NA	411.4	1 042.50	NA
Natural Sciences	113.8	NA	0	113.8	NA
Engineering & Technology	127.4	NA	85	42.4	NA
Medical & Health Sciences	202.6	NA	84.2	118.4	NA
Agricultural & Vet. Sciences	178.2	NA	116.3	61.9	NA
Social Sciences	149	NA	14.4	134.6	NA
Humanities & Arts	76.6	NA	8.28	68.3	NA
Not elsewhere classified	606.4	NA	103.2	503.2	NA

Table 1.8.12 Researchers (HC) by age and sector

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	20 881	NA	6 310	14 571	NA
Under 25 years	196	NA	91	105	NA
25-34 Years	2 698	NA	1 035	1 663	NA
35-44 Years	5 734	NA	1 488	4 246	NA
45-54 Years	5 283	NA	945	4 338	NA
55-64 Years	2 723	NA	298	2 425	NA
65 Years and more	734	NA	41	693	NA
Not Elsewhere classified	3 513	NA	2 412	1 101	NA

Table 1.8.13 R&D personnel (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	85 601	15 094	7 504	61 159	1 844
Natural Sciences	24 580	5 567	2 720	16 036	257
Engineering & Technology	6 393	1 779	852	3 762	1
Medical & Health Sciences	19 830	6 643	1 008	10 852	1 327
Agricultural & Vet. Sciences	5 398	1 072	1 705	2 547	74
Social Sciences	24 782	33	1 219	23 387	143
Humanities & Arts	4 618	0	0	4 576	42
Not elsewhere classified	0	0	0	0	0
Total Female	41 880	7 128	3 607	29 867	1 278
Natural Sciences	10 785	1 500	1 172	7 960	153
Engineering & Technology	2 645	428	348	1 870	0
Medical & Health Sciences	11 859	4 695	668	5 532	964
Agricultural & Vet. Sciences	2 470	486	708	1 228	48
Social Sciences	11 903	19	697	11 101	86
Humanities & Arts	2 217	NA	14	2 176	27
Not elsewhere classified	NA	NA	NA	NA	NA

Table 1.8.14 Researchers (HC) by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	63 122	4 370	3 524	54 784	444
ISCED 8	43 780	466	1 260	42 520	114
ISCED 7	12 922	3 047	1 990	10 932	277
ISCED 6	1 332	NA	NA	1 332	NA
ISCED 5	274	857	274	NA	53
ISCED 4 & Below	NA	NA	NA	NA	NA
Total Female	29 658	1 511	1 836	26 038	273
ISCED 8	20 293	176	602	19 453	62
ISCED 7	8 182	1 044	1 087	5 871	180
ISCED 6	NA	NA	NA	NA	NA
ISCED 5	1 183	291	147	714	31
ISCED 4 & Below	0	NA	NA	NA	NA

Table 1.8.15 Researchers (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	63 122	4 370	3 524	54 784	444
Natural Sciences	15 570	2 453	1 101	14 470	118
Engineering & Technology	3 692	783	328	3 363	0
Medical & Health Sciences	10 245	754	543	9 702	174
Agricultural & Vet. Sciences	2 931	353	665	2 265	34
Social Sciences	21 732	NA	870	20 861	89
Humanities & Arts	4 138	27	16	4 122	28
Not elsewhere classified	0	0	0	0	0
Total Female	29 658	1 511	1 836	26 038	273
Natural Sciences	8 143	571	513	6 997	63
Engineering & Technology	1 954	189	144	1 620	0
Medical & Health Sciences	5 836	542	371	4 802	122
Agricultural & Vet. Sciences	1 575	192	305	1 055	23
Social Sciences	10 219	16	494	9 659	50
Humanities & Arts	1 931	NA	10	1 905	16
Not elsewhere classified	NA	NA	NA	NA	NA

1.9 RWANDA 2023

Table 1.9.1 Distribution of R&D personnel (HC) by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	7 411	1 297	1 775	2 949	1 390
Researchers	3 805	391	676	2 168	570
Technicians	2 181	685	629	384	483
Support Staff	1 425	221	470	397	337
Total Female	2 364	392	590	784	598
Researchers	996	106	169	502	219
Technicians	772	204	238	108	222
Support Staff	596	82	183	174	157

Table 1.9.2 Distribution of R&D personnel (HC) by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	7 411	1 297	1 775	2 949	1 390
Researchers	3 805	391	676	2 168	570
Technicians	2 181	685	629	384	483
Support Staff	1 425	221	470	397	337
Total Female	2 364	392	590	784	598
Researchers	996	106	169	502	219
Technicians	772	204	238	108	222
Support Staff	596	82	183	174	157

Table 1.9.3 Full-time equivalent for R&D personnel by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 655.1	667.6	891.7	1 343.4	752.4
Researchers	1 837.4	215.2	384.6	922.9	314.7
Technicians	1 155.2	347.8	320.0	197.7	289.7
Support Staff	662.5	104.6	187.1	222.8	148.0
Total Female	1 151.0	197.0	290.7	364.3	299.0
Researchers	471.3	56.3	94.7	210.6	109.7
Technicians	408.3	102.0	128.1	52.7	125.5
Support Staff	271.4	38.7	67.9	101.0	63.8

Table 1.9.4 R&D personnel (HC) by level of education, sector and sex

Level of Education (ISCED)	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	7 411	1 297	1 775	2 949	1 390
ISCED 8	1 099	27	87	873	112
ISCED 7	2 500	165	546	1 488	301
ISCED 6	3 149	699	1 118	548	784
ISCED 5	405	245	20	36	104
ISCED 4 & Below	258	161	4	4	89
Total Female	2 364	392	590	784	598
ISCED 8	199	2	15	147	35
ISCED 7	729	40	161	416	112
ISCED 6	1194	220	410	213	351
ISCED 5	138	79	3	8	48
ISCED 4 & Below	104	51	1	0	52

Table 1.9.5 FTE for R&D personnel by level of education, sector and sex

Level of Education (ISCED)	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	3655.4	667.8	891.7	1343.3	752.6
ISCED 8	568.0	13.5	49.9	441.3	63.3
ISCED 7	1216.2	88.7	300.6	649.4	177.5
ISCED 6	1604.2	395.0	527.6	243.5	438.1
ISCED 5	155.5	104.3	11.4	5.6	34.2
ISCED 4 & Below	111.5	66.3	2.2	3.5	39.5

Table 1.9.6 R&D personnel (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	7 411	1 297	1 775 345 225 675 92 293 54 91	2 949	1 390
Natural Sciences	749	89		404	113
Engineering & Technology	842	642		617	82
Medical & Health Sciences	1 164	91		489	401
Agricultural Sciences	355	283		263	108
Social Sciences	1 092	51		799	553
Humanities	396	12		342	34
Not elsewhere classified	126	129		35	99
Total Female	2 364	392	590 125 69 244 23 76 22 31	784	598
Natural Sciences	319	31		113	50
Engineering & Technology	406	158		139	40
Medical & Health Sciences	583	24		119	196
Agricultural & Vet. Sciences	243	118		64	38
Social Sciences	553	24		218	235
Humanities & Arts	161	4		125	10
Not elsewhere classified	99	33		6	29

Table 1.9.7 FTE for R&D personnel by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3655.2	667.8	891.7	1 343.3	752.4
Natural Sciences	566.3	51.7	207.3	243.9	63.4
Engineering & Technology	796.8	353.2	165.9	246.5	31.2
Medical & Health Sciences	722.3	45.6	160.6	251.3	264.8
Agricultural Sciences	398.7	170	61.9	100.9	65.9
Social Sciences	878.2	23.4	229.2	355.0	270.6
Humanities	202.2	6.8	36.1	138.4	20.9
Not elsewhere classified	90.7	17.1	30.7	7.3	35.6

Table 1.9.8 R&D personnel (HC) by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	7 411	1 297	1 775	2 949	1 390
Under 25 years	460	205	59	32	164
25-34 Years	2 798	660	770	769	599
35-44 Years	2 657	330	647	1 217	463
45-54 Years	1 095	74	181	691	149
55-64 Years	365	25	109	219	12
65 Years and more	36	3	9	21	3
Total Female	2 364	92	590	784	598
Under 25 years	196	68	26	15	87
25-34 Years	1 074	231	306	235	302
35-44 Years	756	76	186	326	168
45-54 Years	251	13	46	152	40
55-64 Years	84	4	26	53	1
65 Years and more	3	NA	NA	3	NA

Table 1.9.9 Researchers (HC) by level of education, sector and sex

Level of Education (ISCED)	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	3 805	391	676	2 168	570
ISCED 8	1 059	24	74	855	106
ISCED 7	1 864	131	356	1 192	185
ISCED 6	802	191	245	117	249
ISCED 5	45	20	0	4	21
ISCED 4 & Below	35	25	1	0	9
Total Female	996	106	169	502	219
ISCED 8	191	1	12	143	35
ISCED 7	500	32	90	306	72
ISCED 6	282	61	66	53	102
ISCED 5	14	6	0	0	8
ISCED 4 & Below	9	6	1	0	2

Table 1.9.10 FTE for researchers by level of education, sector and sex

Level of Education (ISCED)	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	1837.6	215.2	384.7	922.9	314.8
ISCED 8	546.6	12.8	42.3	432.6	58.9
ISCED 7	830.6	73.2	200.7	451.8	104.9
ISCED 6	417.7	104.7	141.5	36.5	135.0
ISCED 5	20.9	11.5	0.0	2.0	7.4
ISCED 4 & Below	21.8	13.0	0.2	0.0	8.6

Table 1.9.11 Researchers (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	3 805	391	676	2 168	570
Natural Sciences	492	34	81	321	56
Engineering & Technology	810	216	75	471	48
Medical & Health Sciences	869	17	278	420	154
Agricultural & Vet. Sciences	382	75	57	210	40
Social Sciences	923	37	154	488	244
Humanities & Arts	254	4	9	227	14
Not elsewhere classified	75	8	22	31	14
Total Female	996	106	169	502	219
Natural Sciences	142	11	20	83	28
Engineering & Technology	199	50	24	99	26
Medical & Health Sciences	242	4	73	99	66
Agricultural & Vet. Sciences	94	22	11	48	13
Social Sciences	227	16	32	99	80
Humanities & Arts	79	3	1	72	3
Not elsewhere classified	13	0	8	2	3

Table 1.9.12 FTE for researchers by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	1 837.7	215.3	384.7	923.0	314.7
Natural Sciences	304.4	22.8	64.9	191.6	25.1
Engineering & Technology	362.9	117.7	49.5	178.8	16.9
Medical Sciences	381.2	9.1	73.0	195.6	103.5
Agricultural & Vet. Sciences	176.5	40.2	34.5	84.7	17.1
Social Sciences	471.9	18.1	141.2	176.9	135.7
Humanities & Arts	109.2	1.6	9.0	88.1	10.5
Not elsewhere classified	31.6	5.8	12.6	7.3	5.9
Female	471.3	56.3	94.7	210.6	109.7
Natural Sciences	87.0	5.3	18.2	54.4	9.1
Engineering & Technology	84.9	30.8	12.8	35.0	6.3
Medical Sciences	107.7	1.9	21.0	42.8	42.0
Agricultural & Vet. Sciences	41.3	11.0	6.9	17.9	5.5
Social Sciences	113.7	5.9	29.7	34.7	43.4
Humanities & Arts	29.4	1.4	1.0	24.8	2.2
Not elsewhere classified	7.3	NA	5.1	1.0	1.2

Table 1.9.13 Researchers (HC) by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 805	391	676	2 168	570
Under 25 years	25	38	5	12	70
25-34 Years	963	175	168	457	163
35-44 Years	1 552	129	329	880	214
45-54 Years	856	34	114	597	111
55-64 Years	286	14	55	208	9
65 Years and more	23	1	5	14	3

1.10 SENEGAL 2022

Table 1.10.1 Distribution of R&D personnel (HC) by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	26 390	NA	NA	26 390	NA
Researchers	24 950	NA	NA	24 950	NA
Technicians	571	NA	NA	571	NA
Support Staff	869	NA	NA	869	NA
Total Female	9 513	NA	NA NA	9 513	NA
Researchers	8 996	NA	NA	8 996	NA
Technicians	237	NA	NA	237	NA
Support Staff	280	NA		280	NA

Table 1.10.2 Full-time equivalent for R&D personnel by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	5 584.0	NA	NA	5 584.0	NA
Researchers	4 939.0	NA	NA	4 939.0	NA
Technicians	310.5	NA	NA	310.5	NA
Support Staff	334.6	NA	NA	334.6	NA
Total Female	2 011.0	NA	NA	2 011.0	NA
Researchers	1 779.9	NA	NA	1 779.9	NA
Technicians	122.3	NA	NA	122.3	NA
Support Staff	108.8	NA	NA	108.8	NA

Table 1.10.3 R&D personnel (HC) by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	26 390	NA	NA	26 390	NA
ISCED 8	9 165	NA	NA	9 165	NA
ISCED 7	14 921	NA	NA	14 921	NA
ISCED 6	1 792	NA	NA	1 792	NA
ISCED 5	394	NA	NA	394	NA
ISCED 4 & Below	118	NA	NA	118	NA
Total Female	9 513	NA	NA	9 513	NA
ISCED 8	2 624	NA	NA	2 624	NA
ISCED 7	5 966	NA	NA	5 966	NA
ISCED 6	758	NA	NA	758	NA
ISCED 5	133	NA	NA	133	NA
ISCED 4 & Below	32	NA	NA	32	NA

Table 1.10.4 FTE for R&D personnel by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	5 583.3	NA	NA	5 583.3	NA
ISCED 8	3028.1	NA	NA	3 028.1	NA
ISCED 7	1790.5	NA	NA	1 790.5	NA
ISCED 6	583.5	NA	NA	583.5	NA
ISCED 5	157.6	NA	NA	157.6	NA
ISCED 4 & Below	23.6	NA	NA	23.6	NA
Total Female	8 996.0	NA	NA	8 996	NA
ISCED 8	2 487	NA	NA	2 487	NA
ISCED 7	5 782	NA	NA	5 782	NA
ISCED 6	727	NA	NA	727	NA
ISCED 5	0.0	NA	0.0	0.0	NA
ISCED 4 & Below	0.0	NA	0.0	0.0	NA

Table 1.10.5 R&D personnel (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	26 390	NA	NA	26 390	NA
Natural Sciences	5 678	NA	NA	5 678	NA
Engineering & Technology	1 017	NA	NA	1 017	NA
Medical & Health Sciences	3 975	NA	NA	3 975	NA
Agricultural & Vet. Sciences	781	NA	NA	781	NA
Social Sciences	9 241	NA	NA	9 241	NA
Humanities & Arts	5 451	NA	NA	5 451	NA
Not elsewhere classified	247	NA	NA	247	NA
Total Female	9 513	NA	NA	9 513	NA
Natural Sciences	2 104	NA	NA	2 104	NA
Engineering & Technology	304	NA	NA	304	NA
Medical & Health Sciences	1 316	NA	NA	1 316	NA
Agricultural & Vet. Sciences	278	NA	NA	278	NA
Social Sciences	3 268	NA	NA	3 268	NA
Humanities & Arts	2 158	NA	NA	2 158	NA
Not elsewhere classified	85	NA	NA	85	NA

Table 1.10.6 FTE for R&D personnel by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	5 583.90	NA	NA	5 583.90	NA
Natural Sciences	1 366.70	NA	NA	1 366.70	NA
Engineering & Technology	769.4	NA	NA	769.4	NA
Medical & Health Sciences	479.4	NA	NA	479.4	NA
Agricultural & Vet. Sciences	420.4	NA	NA	420.4	NA
Social Sciences	1 360.80	NA	NA	1 360.80	NA
Humanities & Arts	948.1	NA	NA	948.1	NA
Not elsewhere classified	239.2	NA	NA	239.2	NA

Table 1.10.7 R&D personnel (HC) by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	26 390	NA	NA	26 390	NA
Under 25 years	428	NA	NA	428	NA
25-34 Years	9 898	NA	NA	9 898	NA
35-44 Years	7 405	NA	NA	7 405	NA
45-54 Years	6 182	NA	NA	6 182	NA
55-64 Years	2 165	NA	NA	2 165	NA
65 Years and more	312	NA	NA	312	NA
Total Female	9 513	NA	NA	9 513	NA
Under 25 years	148	NA	NA	148	NA
25-34 Years	3 189	NA	NA	3 189	NA
35-44 Years	2 369	NA	NA	2 369	NA
45-54 Years	2 345	NA	NA	2 345	NA
55-64 Years	1 079	NA	NA	1 079	NA
65 Years and more	85	NA	NA	85	NA
Not Classified	298	NA	NA	298	NA

Table 1.10.8 Researchers (HC) by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	24 950	0	0	24 950	0
ISCED 8	8 767	NA	NA	8 767	NA
ISCED 7	14 399	NA	NA	14 399	NA
ISCED 6	1 572	NA	NA	1 572	NA
ISCED 5	212	NA	NA	212	NA
ISCED 4 & Below	NA	NA	NA	0	NA
Total Female	8 996	0	0	8 996	0
ISCED 8	2 487	NA	NA	2 487	NA
ISCED 7	5 782	NA	NA	5 782	NA
ISCED 6	727	NA	NA	727	NA
ISCED 5	NA	NA	NA	NA	NA
ISCED 4 & Below	NA	NA	NA	NA	NA

Table 1.10.9 FTE for researchers by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	4 939.0	NA	NA	4 939.0	NA
ISCED 8	2630.1	NA	NA	2630.1	NA
ISCED 7	1727.9	NA	NA	1727.9	NA
ISCED 6	496.2	NA	NA	496.2	NA
ISCED 5	84.8	NA	NA	84.8	NA
ISCED 4 & Below	0.0	NA	NA	0.0	NA

Table 1.10.10 Researchers (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	24 950	NA	NA	24 950	NA
Natural Sciences	5 440	NA	NA	5 440	NA
Engineering & Technology	808	NA	NA	808	NA
Medical & Health Sciences	3 727	NA	NA	3 727	NA
Agricultural & Vet. Sciences	549	NA	NA	549	NA
Social Sciences	8 882	NA	NA	8 882	NA
Humanities & Arts	5 297	NA	NA	5 297	NA
Not elsewhere classified	247	NA	NA	247	NA
Female	8 996	NA	NA	8 996	NA
Natural Sciences	2 023	NA	NA	2 023	NA
Engineering & Technology	232	NA	NA	232	NA
Medical Sciences	1 238	NA	NA	1 238	NA
Agricultural & Vet. Sciences	204	NA	NA	204	NA
Social Sciences	3 122	NA	NA	3 122	NA
Humanities & Arts	2 092	NA	NA	2 092	NA
Not elsewhere classified	85	NA	NA	85	NA

Table 1.10.11 FTE for researchers by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	4 939.0	NA	NA	4 939.0	NA
Natural Sciences	1 211.7	NA	NA	1 211.7	NA
Engineering & Technology	652.3	NA	NA	652.3	NA
Medical & Health Sciences	351.4	NA	NA	351.4	NA
Agricultural & Vet. Sciences	329.4	NA	NA	329.4	NA
Social Sciences	1 247.8	NA	NA	1 247.8	NA
Humanities & Arts	907.0	NA	NA	907.0	NA
Not elsewhere classified	239.5	NA	NA	239.5	NA
Female	1 779.9	NA	NA	1 779.9	NA
Natural Sciences	489.6	NA	NA	489.6	NA
Engineering & Technology	228.9	NA	NA	228.9	NA
Medical & Health Sciences	117.4	NA	NA	117.4	NA
Agricultural & Vet. Sciences	124.0	NA	NA	124.0	NA
Social Sciences	412.6	NA	NA	412.6	NA
Humanities & Arts	308.9	NA	NA	308.9	NA
Not elsewhere classified	98.5	NA	NA	98.5	NA

Table 1.10.12 Researchers (HC) by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	24 950	NA	NA	24 950	NA
Under 25 years	356	NA	NA	356	NA
25-34 Years	9 468	NA	NA	9 468	NA
35-44 Years	6 948	NA	NA	6 948	NA
45-54 Years	5 775	NA	NA	5 775	NA
55-64 Years	2 091	NA	NA	2 091	NA
65 Years and more	312	NA	NA	312	NA

1.11 ZAMBIA 2022

Table 1.11.1 Distribution of R&D personnel (HC) by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 429	NA	830	2 599	NA
Researchers	2 531	NA	322	2 209	NA
Technicians	430	NA	232	198	NA
Support Staff	468	NA	276	192	NA
Total Female	991	NA	265	726	NA
Researchers	671	NA	106	565	NA
Technicians	132	NA	76	56	NA
Support Staff	188	NA	83	105	NA

Table 1.11.2 FTE for R&D personnel by occupation, sector and sex

Occupation	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	1 488.2	NA	746.6	741.6	NA
Researchers	940.8	NA	316.3	624.5	NA
Technicians	265.4	NA	205.8	59.6	NA
Support Staff	282.0	NA	224.5	57.5	NA
Total Female	460.6	NA	243.8	216.8	NA
Researchers	274.1	NA	105.8	168.3	NA
Technicians	89.0	NA	72.2	16.8	NA
Support Staff	97.5	NA	65.8	31.7	NA

Table 1.11.3 R&D personnel (HC) by level of education, sector and sex

Level of Education (ISCED)	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	3 429	NA	830 33 135 180 313 169	2 599	NA
ISCED 8	882	NA		849	NA
ISCED 7	1 470	NA		1 335	NA
ISCED 6	405	NA		225	NA
ISCED 5	460	NA		147	NA
ISCED 4 & Below	212	NA		43	NA
Total Female	991	NA	265 9 40 71 96 49	726	NA
ISCED 8	184	NA		175	NA
ISCED 7	411	NA		371	NA
ISCED 6	168	NA		97	NA
ISCED 5	155	NA		59	NA
ISCED 4 & Below	73	NA		24	NA

Table 1.11.4 FTE for R&D personnel by level of education, sector and sex

Level of Education (ISCED)	Total	Business	Government	Higher Educ.	Private Non-Profit
Total	1 488.2	NA	746.6	741.6	NA
ISCED 8	286.6	NA	30.5	256.1	NA
ISCED 7	500.2	NA	134.8	365.4	NA
ISCED 6	243.2	NA	177.0	66.2	NA
ISCED 5	302.8	NA	260.0	42.8	NA
ISCED 4 & Below	155.4	NA	144.3	11.1	NA

Table 1.11.5 R&D personnel (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 429	NA	830	2 599	NA
Natural Sciences	542	NA	87	455	NA
Engineering & Technology	314	NA	12	302	NA
Medical Sciences	806	NA	65	741	NA
Agricultural & Vet. Sciences	797	NA	577	220	NA
Social Sciences	703	NA	84	619	NA
Humanities & Arts	264	NA	5	259	NA
Not elsewhere classified	3	NA	NA	3	NA
Total Female	991	NA	265	726	NA
Natural Sciences	124	NA	29	95	NA
Engineering & Technology	37	NA	NA	37	NA
Medical Sciences	313	NA	23	290	NA
Agricultural & Vet. Sciences	231	NA	170	61	NA
Social Sciences	216	NA	40	176	NA
Humanities & Arts	69	NA	3	66	NA
Not elsewhere classified	1	NA	NA	1	NA

Table 1.11.6 FTE for R&D personnel by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	1 488.10	NA	746.6	741.6	NA
Natural Sciences	222.9	NA	86	136.9	NA
Engineering & Technology	110	NA	11.5	98.5	NA
Medical Sciences	259.6	NA	65	194.6	NA
Agricultural & Vet. Sciences	581.1	NA	518	63.1	NA
Social Sciences	232.5	NA	61.1	171.4	NA
Humanities & Arts	81	NA	5	76	NA
Not elsewhere classified	1	NA	NA	1	NA
Total Female	460.6	NA	243.8	216.8	NA
Natural Sciences	57.3	NA	29	28.3	NA
Engineering & Technology	14.4	NA	0	14.4	NA
Medical Sciences	101.5	NA	23	78.5	NA
Agricultural & Vet. Sciences	181.3	NA	165	16.3	NA
Social Sciences	80.7	NA	23.8	56.9	NA
Humanities & Arts	25.1	NA	3	22.1	NA
Not elsewhere classified	0.3	NA	0	0.3	NA

Table 1.11.7 R&D personnel (HC) by age, sector and sex

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	3 429	NA	830	2 599	NA
Under 25 years	12	NA	4	8	NA
25-34 Years	381	NA	150	231	NA
35-44 Years	1 148	NA	336	812	NA
45-54 Years	1 109	NA	255	854	NA
55-64 Years	644	NA	83	561	NA
65 Years and more	135	NA	2	133	NA
Total Female	991	NA	265	726	NA
Under 25 years	3	NA	1	2	NA
25-34 Years	187	NA	69	118	NA
35-44 Years	372	NA	96	276	NA
45-54 Years	266	NA	71	195	NA
55-64 Years	139	NA	28	111	NA
65 Years and more	24	NA	0	24	NA

Table 1.11.8 Researchers (HC) by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	2 531	NA	322	2 209	NA
ISCED 8	869	NA	30	839	NA
ISCED 7	1 404	NA	133	1 271	NA
ISCED 6	246	NA	159	87	NA
ISCED 5	12	NA	NA	12	NA
ISCED 4 & Below	NA	NA	NA	NA	NA
Total Female	671	NA	106	565	NA
ISCED 8	176	NA	7	169	NA
ISCED 7	386	NA	38	348	NA
ISCED 6	103	NA	61	42	NA
ISCED 5	6	NA	0	6	NA
ISCED 4 & Below	0	NA	0	0	NA

Table 1.11.9 FTE for researchers by level of education, sector and sex

Level of Education	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	940.7	NA	316.3	624.5	NA
ISCED 8	280.6	NA	27.5	253.1	NA
ISCED 7	478.9	NA	132.8	346.1	NA
ISCED 6	179	NA	156	23	NA
ISCED 5	2.3	NA	NA	2.3	NA
ISCED 4 & Below	NA	NA	NA	NA	NA
Total Female	274.1	NA	105.8		NA
ISCED 8	69.3	NA	7	168.3	NA
ISCED 7	132.2	NA	37.8	62.3	NA
ISCED 6	71.8	NA	61	94.4	NA
ISCED 5	0.8	NA	NA	10.8	NA
ISCED 4 & Below	NA	NA	NA	0.8	NA

Table 1.11.10 Researchers (HC) by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	2 531	NA	322	2 209	NA
Natural Sciences	443	NA	44	399	NA
Engineering & Technology	240	NA	4	236	NA
Medical Sciences	638	NA	31	607	NA
Agricultural & Vet. Sciences	384	NA	234	150	NA
Social Sciences	578	NA	9	569	NA
Humanities & Arts	248	NA	0	248	NA
Not elsewhere classified	0	NA	0	0	NA
Total Female	671	NA	106	565	NA
Natural Sciences	96	NA	17	79	NA
Engineering & Technology	21	NA	0	21	NA
Medical Sciences	229	NA	8	221	NA
Agricultural & Vet. Sciences	114	NA	76	38	NA
Social Sciences	147	NA	5	142	NA
Humanities & Arts	64	NA	0	64	NA
Not elsewhere classified	0	NA	0	0	NA

Table 1.11.11 FTE for researchers by field of R&D, sector and sex

Field of R&D	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	940.7	NA	316.3	624.5	NA
Natural Sciences	163.1	NA	43.0	120.1	NA
Engineering & Technology	82.3	NA	3.5	78.8	NA
Medical Sciences	185.6	NA	31.0	154.6	NA
Agricultural & Vet. Sciences	272.0	NA	230.0	42.0	NA
Social Sciences	165.1	NA	8.8	156.3	NA
Humanities & Arts	72.7	NA	0.0	72.7	NA
Not elsewhere classified	0	NA	0.0	0.0	NA
Total Female	274.2	NA	105.8	168.4	NA
Natural Sciences	40.4	NA	17.0	23.4	NA
Engineering & Technology	9.7	NA	0.0	9.7	NA
Medical Sciences	66.0	NA	8.0	58.0	NA
Agricultural & Vet. Sciences	85.5	NA	76.0	9.5	NA
Social Sciences	51.5	NA	4.8	46.7	NA
Humanities & Arts	21.1	NA	0.0	21.1	NA
Not elsewhere classified	0.0	NA	0	0.0	NA

Table 1.11.12 Researchers (HC) by age and sector

Age	Total	Business	Government	Higher Educ.	Private Non-Profit
Total All	2 531	NA	322	2 209	NA
Under 25 years	8	NA	0	8	NA
25-34 Years	207	NA	26	181	NA
35-44 Years	807	NA	150	657	NA
45-54 Years	847	NA	109	738	NA
55-64 Years	535	NA	36	499	NA
65 Years and more	127	NA	1	126	NA
Total Female	671	NA	106	565	NA
Under 25 years	2	NA	0	2	NA
25-34 Years	103	NA	16	87	NA
35-44 Years	260	NA	52	208	NA
45-54 Years	194	NA	31	163	NA
55-64 Years	92	NA	7	85	NA
65 Years and more	20	NA	0	20	NA

A2. BUSINESS INNOVATION REPORTING TEMPLATE

2.1 BUSINESS INNOVATION SURVEY REPORTING TEMPLATE AS PER THE OSLO MANUAL (OECD-EUROSTATS, 2018)

ASTII templates are with OECD instruments

Variables		Variable label	Total (All enterprises)	Firm size			Total (All enterprises)	Economic activity (ISIC Sectors)			Total (All enterprises)	R&D status	
				Small (10 to 49 persons employed)	Medium (50 to 249 persons employed)	Large (250+ persons employed)		Manufacturing ISIC4 :C ISIC3: D	Firms in ISIC4: A to B ISIC3: A to C	Firms in ISIC4: D to U ISIC3: E to Q		R&D-active (in-house and/or external)	No R&D
Please report data in number of firms and weighted													
BUS1a	Total number of enterprises (population) in the Country (if received from the National Statistics Office / Revenue)	NAT_BUS_POP											
BUS1b	Total number of enterprises targeted for the survey (if received from the National Statistics Office)	BUS_SURVEY_POP											
BUS1c	Total number of enterprises that returned the questionnaire (Sample)	BUS_SAMPLE											

Variables		Variable label	Total (All enterprises)	Firm size			Total (All enterprises)	Economic activity (ISIC Sectors)			Total (All enterprises)	R&D status	
				Small (10 to 49 persons employed)	Medium (50 to 249 persons employed)	Large (250+ persons employed)		Manufacturing ISIC4 :C ISIC3: D	Firms in ISIC4: A to B ISIC3: A to C	Firms in ISIC4: D to U ISIC3: E to Q		R&D-active (in-house and/or external)	No R&D
	Types of innovation												
2	Innovative enterprises (product OR business process)	INN_PPOM											
3	Innovation active enterprises (innovative enterprises (INN_OSLO) as well as firms with innovation activities that have not necessarily led to an innovation)*	INN_PPOM_ACTV											
4	Product innovative enterprises	INN_P											
5	Goods	INN_PG											
6	Services	INN_PS											
7	Product innovative enterprises that developed products ONLY on their own	INN_PGS_OFIRM											

Variables		Variable label	Total (All enterprises)	Firm size			Total (All enterprises)	Economic activity (ISIC Sectors)			Total (All enterprises)	R&D status	
				Small (10 to 49 persons employed)	Medium (50 to 249 persons employed)	Large (250+ persons employed)		Manufacturing ISIC4 :C ISIC3: D	Firms in ISIC4: A to B ISIC3: A to C	Firms in ISIC4: D to U ISIC3: E to Q		R&D-active (in-house and/or external)	No R&D
8	Product innovative enterprises with innovations that were new to the firm's market	INN_PGS_ OMARKET											
9	Business process innovative enterprises (Process, Marketing & Orgnaisational)	INN_ACT_ POM											
10	Production process (goods or services)	POM_GS											
11	Distribution and logistics method	POM_DL											
12	Marketing and sales Method	POM_ MARK											
13	Information and communication systems	POM_ICT											

Variables		Variable label	Total (All enterprises)	Firm size			Total (All enterprises)	Economic activity (ISIC Sectors)			Total (All enterprises)	R&D status	
				Small (10 to 49 persons employed)	Medium (50 to 249 persons employed)	Large (250+ persons employed)		Manufacturing ISIC4 :C ISIC3: D	Firms in ISIC4: A to B ISIC3: A to C	Firms in ISIC4: D to U ISIC3: E to Q		R&D-active (in-house and/or external)	No R&D
14	Administration and management (accounting, external relations, human resource management)	POM_ ADMAN											
15	Business process innovative enterprises that developed products ONLY on their own	POM_P											
Innovation activities													
16	Product or business process innovative enterprises which are R&D active	INN_ PPOM_RD											
Public financial support for innovation activities													
17	Firms receiving tax relief for R&D or other innovation activities	TXR											

Variables		Variable label	Total (All enterprises)	Firm size			Total (All enterprises)	Economic activity (ISIC Sectors)			Total (All enterprises)	R&D status	
				Small (10 to 49 persons employed)	Medium (50 to 249 persons employed)	Large (250+ persons employed)		Manufacturing ISIC4 :C ISIC3: D	Firms in ISIC4: A to B ISIC3: A to C	Firms in ISIC4: D to U ISIC3: E to Q		R&D-active (in-house and/or external)	No R&D
18	Firms receiving funding for innovation (including R&D and excluding contracts for goods and services) from the national government or local and regional authorities	GOVSTI											
19	Firms receiving funding for innovation (including R&D and excluding contracts for goods and services) from the national government or local and regional authorities OR tax relief for R&D or other innovation activities	GOVSTI_TX											

Variables		Variable label	Total (All enterprises)	Firm size			Total (All enterprises)	Economic activity (ISIC Sectors)			Total (All enterprises)	R&D status	
				Small (10 to 49 persons employed)	Medium (50 to 249 persons employed)	Large (250+ persons employed)		Manufacturing ISIC4 :C ISIC3: D	Firms in ISIC4: A to B ISIC3: A to C	Firms in ISIC4: D to U ISIC3: E to Q		R&D-active (in-house and/or external)	No R&D
Innovation co-operation partners													
20	Enterprises co-operating on innovation activities (including R&D)	COOP_ ACTY											
21	Enterprises co-operating on innovation activities with private business enterprise outside the enterprise group	COOP_ ACTY_OUT											
22	Enterprises co-operating on innovation activities with enterprise within the enterprise group	COOP_ ACTY_INN											

Variables		Variable label	Total (All enterprises)	Firm size			Total (All enterprises)	Economic activity (ISIC Sectors)			Total (All enterprises)	R&D status	
				Small (10 to 49 persons employed)	Medium (50 to 249 persons employed)	Large (250+ persons employed)		Manufacturing ISIC4 :C ISIC3: D	Firms in ISIC4: A to B ISIC3: A to C	Firms in ISIC4: D to U ISIC3: E to Q		R&D-active (in-house and/or external)	No R&D
23	"Enterprises co-operating on innovation activities with universities or other higher education institutions"	COOP_ ACTY_HE											
24	Enterprises co-operating on innovation activities with public R&D institutes	COOP_ ACTY_ GOV											
25	Enterprises co-operating on innovation activities with clients or customers from the public sector*	COOP_ ACTY_ GOV_CC											
26	Enterprises co-operating on innovation activities with non-profit organisations	COOP_ ACTY_ GOV_NPO											

	Variables	Variable label	Total (All enterprises)	Firm size			Total (All enterprises)	Economic activity (ISIC Sectors)			Total (All enterprises)	R&D status	
				Small (10 to 49 persons employed)	Medium (50 to 249 persons employed)	Large (250+ persons employed)		Manufacturing ISIC4 :C ISIC3: D	Firms in ISIC4: A to B ISIC3: A to C	Firms in ISIC4: D to U ISIC3: E to Q		R&D-active (in-house and/or external)	No R&D
27	Enterprises co-operating internationally, with collaboration partners from abroad	COOP_ ACTY_ GOV_ABR											
	Use of innovation protection methods												
28	Enterprises that applied for patents (excluding utility models**)	IP_PAT											
29	Enterprises that registered a design	IP_DESG											
30	Enterprises that registered a trademark	IP_TRADM	0				0				0		
	Innovation and markets												

*In some countries this can be inferred from ongoing or abandoned innovation activities; in some others, it can be derived from ALL the different types of innovation activities (including R&D) that have not necessarily led to an innovation.

(**) Please refer to the definition of utility models (not to be confused with "utility" patents/patents for inventions, e.g. as defined by USPTO)

Instructions: (1) Please report data weighted and in number of firms, number of employees or in national currency, as specified in the tabl

2.2 BUSINESS SURVEY REPORTING TEMPLATE FOR ALL NATIONAL ECONOMIC SECTORS – ISIC REV3

BUSINESS INNOVATION SURVEY | Type of Innovators: (1) Product & (2) Business Process [(2.1) Production Process, (2.2) Organisational Methods and (2.3) Marketing Method)] **BUSINESS INNOVATION SURVEY: Year……. To Year ……. NUMBER OF FIRMS & WEIGHTED BY ECONOMIC SUB-SECTORS** Source:https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf		Total number of enterprises	Innovative enterprises (product OR Business process Innovators) INN_PPOM	Innovation active enterprises (product OR Business process) INN_ACT_PPOM	Product innovative enterprises INN_P	
A	**AGRICULTURE, HUNTING AND FORESTRY**					
01 – Agriculture, hunting and related service activities						
02 – Forestry, logging and related service activities						
Total (A)		0	0	0	0	
B	**FISHING**					
05 – Fishing, aquaculture and service activities incidental to fishing						
Total (B)		0	0	0	0	
C	**MINING AND QUARRYING**					
10 – Mining of coal and lignite; extraction of peat						
11 – Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction, excluding surveying						
12 – Mining of uranium and thorium ores						
13 – Mining of metal ores						
14 – Other mining and quarrying						
Total (C)		0	0	0	0	
D	**MANUFACTURING**					
15 – Manufacture of food products and beverages						
16 – Manufacture of tobacco products						
17 – Manufacture of textiles						
18 – Manufacture of wearing apparel; dressing and dyeing of fur						
19 – Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear						
20 – Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials						

	Business process innovative enterprises	Expenditures on R&D (including in-house AND contracted-out R&D) in Local Currency	Firms receiving government funding or tax relief for R&D or other innovation activities	Innovative enterprises with environmental benefits	Innovative firms with Intellectual Property Rights	Innovative firms with radical innovations (first in the world)
	INN_POM	INN_PPOM_RD	TXR	INN_PPOM_ENV	INN_PPOPM_IP	INN_RADICAL
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0

BUSINESS INNOVATION SURVEY | Type of Innovators: (1) Product & (2) Business Process [(2.1) Production Process, (2.2) Organisational Methods and (2.3) Marketing Method)]	Total number of enterprises	Innovative enterprises (product OR Business process Innovators)	Innovation active enterprises (product OR Business process)	Product innovative enterprises	
BUSINESS INNOVATION SURVEY: Year……. To Year ……. **NUMBER OF FIRMS & WEIGHTED BY ECONOMIC SUB-SECTORS**					
Source:https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf		INN_PPOM	INN_ACT_PPOM	INN_P	
21 – Manufacture of paper and paper products					
22 – Publishing, printing and reproduction of recorded media					
23 – Manufacture of coke, refined petroleum products and nuclear fuel					
24 – Manufacture of chemicals and chemical products					
25 – Manufacture of rubber and plastics products					
26 – Manufacture of other non-metallic mineral products					
27 – Manufacture of basic metals					
28 – Manufacture of fabricated metal products, except machinery and equipment					
29 – Manufacture of machinery and equipment n.e.c.					
30 – Manufacture of office, accounting and computing machinery 31 – Manufacture of electrical machinery and apparatus n.e.c.					
32 – Manufacture of radio, television and communication equipment and apparatus					
33 – Manufacture of medical, precision and optical instruments, watches and clocks					
34 – Manufacture of motor vehicles, trailers and semi-trailers					
35 – Manufacture of other transport equipment					
36 – Manufacture of furniture; manufacturing n.e.c.					
37 – Recycling					
Total (D)	0	0	0	0	
E **ELECTRICITY, GAS AND WATER SUPPLY**					
40 – Electricity, gas, steam and hot water supply					
41 – Collection, purification and distribution of water					
Total (E)	0	0	0	0	

	Business process innovative enterprises	Expenditures on R&D (including in-house AND contracted-out R&D) in Local Currency	Firms receiving government funding or tax relief for R&D or other innovation activities	Innovative enterprises with environmental benefits	Innovative firms with Intellectual Property Rights	Innovative firms with radical innovations (first in the world)
	INN_POM	INN_PPOM_RD	TXR	INN_PPOM_ENV	INN_PPOPM_IP	INN_RADICAL
	0	0	0	0	0	0
	0	0	0	0	0	0

BUSINESS INNOVATION SURVEY | Type of Innovators: (1) Product & (2) Business Process [(2.1) Production Process, (2.2) Organisational Methods and (2.3) Marketing Method)]		Total number of enterprises	Innovative enterprises (product OR Business process Innovators)	Innovation active enterprises (product OR Business process)	Product innovative enterprises	
BUSINESS INNOVATION SURVEY: **Year……. To Year …….** **NUMBER OF FIRMS & WEIGHTED BY ECONOMIC SUB-SECTORS**						
Source:https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf			INN_PPOM	INN_ACT_PPOM	INN_P	
F	**CONSTRUCTION**					
45 – Construction						
Total (F)		0	0	0	0	
G	**WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES, MOTORCYCLES AND PERSONAL AND HOUSEHOLD GOODS**					
50 – Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel						
51 – Wholesale trade and commission trade, except of motor vehicles and motorcycles						
52 – Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods						
Total (G)		0	0	0	0	
H	**CONSTRUCTION**					
55 – Hotels and restaurants						
Total (H)		0	0	0	0	
I	**TRANSPORT, STORAGE AND COMMUNICATIONS**					
60 – Land transport; transport via pipelines						
61 – Water transport						
62 – Air transport						
63 – Supporting & auxiliary transport activities; activities of travel agencies						
64 – Post and telecommunications						
Total (I)		0	0	0	0	
J	**FINANCIAL INTERMEDIATION**					
65 – Financial intermediation, except insurance and pension funding						
66 – Insurance and pension funding, except compulsory social security						
67 – Activities auxiliary to financial intermediation						
Total (J)		0	0	0	0	

	Business process innovative enterprises	Expenditures on R&D (including in-house AND contracted-out R&D) in Local Currency	Firms receiving government funding or tax relief for R&D or other innovation activities	Innovative enterprises with environmental benefits	Innovative firms with Intellectual Property Rights	Innovative firms with radical innovations (first in the world)
	INN_POM	INN_PPOM_RD	TXR	INN_PPOM_ENV	INN_PPOPM_IP	INN_RADICAL
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0

BUSINESS INNOVATION SURVEY | Type of Innovators: (1) Product & (2) Business Process [(2.1) Production Process, (2.2) Organisational Methods and (2.3) Marketing Method)] **BUSINESS INNOVATION SURVEY: Year……. To Year ……. NUMBER OF FIRMS & WEIGHTED BY ECONOMIC SUB-SECTORS**	Total number of enterprises	Innovative enterprises (product OR Business process Innovators)	Innovation active enterprises (product OR Business process)	Product innovative enterprises	
Source:https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf		INN_PPOM	INN_ACT_PPOM	INN_P	
K REAL ESTATE, RENTING AND BUSINESS ACTIVITIES					
70 – Real estate activities					
71 – Renting of machinery and equipment without operator and of personal and household goods					
72 – Computer and related activities					
73 – Research and development					
74 – Other business activities					
Total (K)	0	0	0	0	
L PUBLIC ADMINISTRATION AND DEFENCE; COMPULSORY SOCIAL SECURITY					
75 – Public administration and defence; compulsory social security					
Total (L)	0	0	0	0	
M EDUCATION					
80 – Education					
Total (M)	0	0	0	0	
N HEALTH AND SOCIAL WORK					
85 – Health and social work					
Total (N)	0	0	0	0	
O WORK OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICE ACTIVITIES					
90 – Sewage and refuse disposal, sanitation and similar activities					
91 – Activities of membership organisations n.e.c.					
92 – Recreational, cultural and sporting activities					
93 – Other service activities					
Total (O)	0	0	0	0	

	Business process innovative enterprises	Expenditures on R&D (including in-house AND contracted-out R&D) in Local Currency	Firms receiving government funding or tax relief for R&D or other innovation activities	Innovative enterprises with environmental benefits	Innovative firms with Intellectual Property Rights	Innovative firms with radical innovations (first in the world)
	INN_POM	INN_PPOM_RD	TXR	INN_PPOM_ENV	INN_PPOPM_IP	INN_RADICAL
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0

BUSINESS INNOVATION SURVEY | Type of Innovators: (1) Product & (2) Business Process [(2.1) Production Process, (2.2) Organisational Methods and (2.3) Marketing Method)] **BUSINESS INNOVATION SURVEY: Year……. To Year ……. NUMBER OF FIRMS & WEIGHTED BY ECONOMIC SUB-SECTORS** Source:https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf		Total number of enterprises	Innovative enterprises (product OR Business process Innovators)	Innovation active enterprises (product OR Business process)	Product innovative enterprises	
			INN_PPOM	INN_ACT_PPOM	INN_P	
P	**ACTIVITIES OF PRIVATE HOUSEHOLDS AS EMPLOYERS AND UNDIFFERENTIATED PRODUCTION ACTIVITIES OF PRIVATE HOUSEHOLDS**					
95 – Activities of private households as employers of domestic staff						
96 – Undifferentiated goods-producing activities of private households for own use						
97 – Undifferentiated service-producing activities of private households for own use						
Total (P)		0	0	0	0	
Q	**EXTRATERRITORIAL ORGANISATIONS AND BODIES**					
99 – Extraterritorial organisations and bodies						
Total (Q)		0	0	0	0	
GRAND TOTAL		0	0	0	0	

	Business process innovative enterprises	Expenditures on R&D (including in-house AND contracted-out R&D) in Local Currency	Firms receiving government funding or tax relief for R&D or other innovation activities	Innovative enterprises with environmental benefits	Innovative firms with Intellectual Property Rights	Innovative firms with radical innovations (first in the world)
	INN_POM	INN_PPOM_RD	TXR	INN_PPOM_ENV	INN_PPOPM_IP	INN_RADICAL
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0

2.3 BUSINESS SURVEY REPORTING TEMPLATE FOR ALL NATIONAL ECONOMIC SECTORS – ISIC REV4

BUSINESS INNOVATION SURVEY | Type of Innovators: (1) Product & (2) Business Process [(2.1) Production Process, (2.2) Organisational Methods and (2.3) Marketing Method)]	Total number of enterprises	Innovative enterprises (product OR Business process Innovators)	Innovation active enterprises (product OR Business process)	Product innovative enterprises	
BUSINESS INNOVATION SURVEY: Year……. To Year ……. **NUMBER OF FIRMS & WEIGHTED BY ECONOMIC SUB-SECTORS**					
Source:https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf		INN_PPOM	INN_ACT_PPOM	INN_P	
A **AGRICULTURE, FORESTRY AND FISHING**					
01 – Crop and animal production, hunting and related service activities					
02 – Forestry and logging					
03 – Fishing and aquaculture					
Total (A)	0	0	0	0	
B **MINING AND QUARRYING**					
05 – Mining of coal and lignite					
06 – Extraction of crude petroleum and natural gas					
07 – Mining of metal ores					
08 – Other mining and quarrying					
09 – Mining support service activities					
Total (B)	0	0	0	0	
C **MANUFACTURING**					
10 – Manufacture of food products					
11 – Manufacture of beverages					
12 – Manufacture of tobacco products					
13 – Manufacture of textiles					
14 – Manufacture of wearing apparel					
15 – Manufacture of leather and related products					
16 – Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials					
17 – Manufacture of paper and paper products					
18 – Printing and reproduction of recorded media					
19 – Manufacture of coke and refined petroleum products					
20 – Manufacture of chemicals and chemical products					
21 – Manufacture of basic pharmaceutical products and pharmaceutical preparations					

	Business process innovative enterprises	Expenditures on R&D (including in-house AND contracted-out R&D) in Local Currency	Firms receiving government funding or tax relief for R&D or other innovation activities	Innovative enterprises with environmental benefits	Innovative firms with Intellectual Property Rights	Innovative firms with radical innovations (first in the world)
	INN_POM	INN_PPOM_RD	TXR	INN_PPOM_ENV	INN_PPOPM_IP	INN_RADICAL
	0	0	0	0	0	0
	0	0	0	0	0	0

BUSINESS INNOVATION SURVEY | Type of Innovators: (1) Product & (2) Business Process [(2.1) Production Process, (2.2) Organisational Methods and (2.3) Marketing Method)] **BUSINESS INNOVATION SURVEY:** **Year……. To Year …….** **NUMBER OF FIRMS & WEIGHTED BY ECONOMIC SUB-SECTORS**	**Total number of enterprises**	**Innovative enterprises (product OR Business process Innovators)**	**Innovation active enterprises (product OR Business process)**	**Product innovative enterprises**	
Source:https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf		**INN_PPOM**	**INN_ACT_PPOM**	**INN_P**	
22 – Manufacture of rubber and plastics products					
23 – Manufacture of other non-metallic mineral products					
24 – Manufacture of basic metals					
25 – Manufacture of fabricated metal products, except machinery and equipment					
26 – Manufacture of computer, electronic and optical products					
32 – Manufacture of radio, television and communication equipment and apparatus					
27 – Manufacture of electrical equipment					
28 – Manufacture of machinery and equipment n.e.c.					
29 – Manufacture of motor vehicles, trailers and semi-trailers					
30 – Manufacture of other transport equipment					
31 – Manufacture of furniture					
32 – Other manufacturing					
33 – Repair and installation of machinery and equipment					
Total (C)	0	0	0	0	
D **ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY**					
35 – Electricity, gas, steam and air conditioning supply					
Total (D)	0	0	0	0	
E **WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES**					
36 – Water collection, treatment and supply					
37 – Sewerage					
38 – Waste collection, treatment and disposal activities; materials recovery					
39 – Remediation activities and other waste management services					
Total (E)	0	0	0	0	

	Business process innovative enterprises	Expenditures on R&D (including in-house AND contracted-out R&D) in Local Currency	Firms receiving government funding or tax relief for R&D or other innovation activities	Innovative enterprises with environmental benefits	Innovative firms with Intellectual Property Rights	Innovative firms with radical innovations (first in the world)
	INN_POM	INN_PPOM_RD	TXR	INN_PPOM_ENV	INN_PPOPM_IP	INN_RADICAL
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0

BUSINESS INNOVATION SURVEY | Type of Innovators: (1) Product & (2) Business Process [(2.1) Production Process, (2.2) Organisational Methods and (2.3) Marketing Method)] **BUSINESS INNOVATION SURVEY:** **Year……. To Year …….** **NUMBER OF FIRMS & WEIGHTED BY ECONOMIC SUB-SECTORS** Source:https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf	**Total number of enterprises**	**Innovative enterprises (product OR Business process Innovators)**	**Innovation active enterprises (product OR Business process)**	**Product innovative enterprises**	
		INN_PPOM	**INN_ACT_PPOM**	**INN_P**	
F **ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY**					
41 – Construction of buildings					
42 – Civil engineering					
43 – Specialised construction activities					
Total (F)	0	0	0	0	
G **WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES**					
45 – Wholesale and retail trade and repair of motor vehicles and motorcycles					
46 – Wholesale trade, except of motor vehicles and motorcycles					
47 – Retail trade, except of motor vehicles and motorcycles					
Total (G)	0	0	0	0	
H **TRANSPORT & STORAGE**					
49 – Land transport and transport via pipelines					
50 – Water transport					
51 – Air transport					
52 – Warehousing and support activities for transportation					
53 – Postal and courier activities					
Total (H)	0	0	0	0	
I **ACCOMMODATION AND FOOD SERVICE ACTIVITIES**					
55 – Accommodation					
56 – Food and beverage service activities					
Total (I)	0	0	0	0	

	Business process innovative enterprises	Expenditures on R&D (including in-house AND contracted-out R&D) in Local Currency	Firms receiving government funding or tax relief for R&D or other innovation activities	Innovative enterprises with environmental benefits	Innovative firms with Intellectual Property Rights	Innovative firms with radical innovations (first in the world)
	INN_POM	INN_PPOM_RD	TXR	INN_PPOM_ENV	INN_PPOPM_IP	INN_RADICAL
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0

BUSINESS INNOVATION SURVEY | Type of Innovators: (1) Product & (2) Business Process [(2.1) Production Process, (2.2) Organisational Methods and (2.3) Marketing Method)] **BUSINESS INNOVATION SURVEY:** **Year……. To Year …….** **NUMBER OF FIRMS & WEIGHTED BY ECONOMIC SUB-SECTORS** Source:https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf	Total number of enterprises	Innovative enterprises (product OR Business process Innovators)	Innovation active enterprises (product OR Business process)	Product innovative enterprises	
		INN_PPOM	INN_ACT_PPOM	INN_P	
J INFORMATION AND COMMUNICATION					
58 – Publishing activities					
71 – Renting of machinery and equipment without operator and of personal and household goods					
59 – Motion picture, video and television programme production, sound recording and music publishing activities					
60 – Programming and broadcasting activities					
61 – Telecommunications					
62 – Computer programming, consultancy and related activities					
63 – Information service activities					
Total (J)	0	0	0	0	
K FINANCIAL AND INSURANCE ACTIVITIES					
64 – Financial service activities, except insurance and pension funding					
65 – Insurance, reinsurance and pension funding, except compulsory social security					
66 – Activities auxiliary to financial service and insurance activities					
Total (K)	0	0	0	0	
L REAL ESTATE ACTIVITIES					
68 – Real estate activities					
Total (L)	0	0	0	0	
M PROFESSIONAL, SCIENTIFIC AND TECHNICAL ACTIVITIES					
69 – Legal and accounting activities					
70 – Activities of head offices; management consultancy activities					
71 – Architectural and engineering activities; technical testing and analysis					
72 – Scientific research and development					
73 – Advertising and market research					
74 – Other professional, scientific and technical activities					
75 – Veterinary activities					
Total (M)	0	0	0	0	

	Business process innovative enterprises	Expenditures on R&D (including in-house AND contracted-out R&D) in Local Currency	Firms receiving government funding or tax relief for R&D or other innovation activities	Innovative enterprises with environmental benefits	Innovative firms with Intellectual Property Rights	Innovative firms with radical innovations (first in the world)
	INN_POM	INN_PPOM_RD	TXR	INN_PPOM_ENV	INN_PPOPM_IP	INN_RADICAL
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0

BUSINESS INNOVATION SURVEY | Type of Innovators: (1) Product & (2) Business Process [(2.1) Production Process, (2.2) Organisational Methods and (2.3) Marketing Method)] **BUSINESS INNOVATION SURVEY: Year……. To Year …….** **NUMBER OF FIRMS & WEIGHTED BY ECONOMIC SUB-SECTORS** Source:https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf		Total number of enterprises	Innovative enterprises (product OR Business process Innovators)	Innovation active enterprises (product OR Business process)	Product innovative enterprises	
			INN_PPOM	INN_ACT_PPOM	INN_P	
N	ADMINISTRATIVE AND SUPPORT SERVICE ACTIVITIES					
77 – Rental and leasing activities						
78 – Employment activities						
79 – Travel agency, tour operator, reservation service and related activities						
80 – Security and investigation activities						
80 – Security and investigation activities						
81 – Services to buildings and landscape activities						
82 – Office administrative, office support and other business support activities						
Total (N)		0	0	0	0	
O	PUBLIC ADMINISTRATION AND DEFENCE; COMPULSORY SOCIAL SECURITY					
84 – Public administration and defence; compulsory social security						
Total (O)		0	0	0	0	
P	EDUCATION					
85 – Education						
Total (P)		0	0	0	0	
Q	HUMAN HEALTH AND SOCIAL WORK ACTIVITIES					
86 – Human health activities						
87 – Residential care activities						
88 – Social work activities without accommodation						
Total (Q)		0	0	0	0	
R	ARTS, ENTERTAINMENT AND RECREATION					
90 – Creative, arts and entertainment activities						
91 – Libraries, archives, museums and other cultural activities						
92 – Gambling and betting activities						

	Business process innovative enterprises	Expenditures on R&D (including in-house AND contracted-out R&D) in Local Currency	Firms receiving government funding or tax relief for R&D or other innovation activities	Innovative enterprises with environmental benefits	Innovative firms with Intellectual Property Rights	Innovative firms with radical innovations (first in the world)
	INN_POM	INN_PPOM_RD	TXR	INN_PPOM_ENV	INN_PPOPM_IP	INN_RADICAL
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0

BUSINESS INNOVATION SURVEY | Type of Innovators: (1) Product & (2) Business Process [(2.1) Production Process, (2.2) Organisational Methods and (2.3) Marketing Method)]	Total number of enterprises	Innovative enterprises (product OR Business process Innovators)	Innovation active enterprises (product OR Business process)	Product innovative enterprises	
BUSINESS INNOVATION SURVEY: Year....... To Year .... **NUMBER OF FIRMS & WEIGHTED BY ECONOMIC SUB-SECTORS**					
Source:https://unstats.un.org/unsd/publication/seriesm/seriesm_4rev4e.pdf		INN_PPOM	INN_ACT_PPOM	INN_P	
93 – Sports activities and amusement and recreation activities					
Total (R)	0	0	0	0	
S **OTHER SERVICE ACTIVITIES**					
94 – Activities of membership organisations					
95 – Repair of computers and personal and household goods					
96 – Other personal service activities					
Total (S)	0	0	0	0	
T **ACTIVITIES OF HOUSEHOLDS AS EMPLOYERS; UNDIFFERENTIATED GOODS- AND SERVICES-PRODUCING ACTIVITIES OF HOUSEHOLDS FOR OWN USE**					
97 – Activities of households as employers of domestic personnel					
98 – Undifferentiated goods- and services-producing activities of private households for own use					
Total (T)	0	0	0	0	
U **ACTIVITIES OF EXTRATERRITORIAL ORGANISATIONS AND BODIES**					
99 – Activities of extraterritorial organisations and bodies					
Total (U)	0	0	0	0	
GRAND TOTAL	0	0	0	0	

	Business process innovative enterprises	Expenditures on R&D (including in-house AND contracted-out R&D) in Local Currency	Firms receiving government funding or tax relief for R&D or other innovation activities	Innovative enterprises with environmental benefits	Innovative firms with Intellectual Property Rights	Innovative firms with radical innovations (first in the world)
	INN_POM	INN_PPOM_RD	TXR	INN_PPOM_ENV	INN_PPOPM_IP	INN_RADICAL
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0

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AFRICAN INNOVATION OUTLOOK

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